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THE MICROSTRUCTURE OF TITANIFEROUS MAGNETITES.[1]

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The manner of the occurrence of the titanium in titaniferous magnetites is a question which has been repeatedly discussed and on which divergent opinions have been expressed, but hitherto no attempt has been made to solve the problem by a systematic investigation of the titaniferous ores. Some believed the ores were merely mechanical aggregates of ilmenite and magnetite, others maintained that the titanium was contained in the magnetite molecule, in which it replaced a portion of the iron.

The solution of the problem is not only of scientific interest, but also of practical importance. In the days of the old charcoal furnaces, titaniferous iron ores were used to a limited extent; but even then, they were in bad repute among the iron-masters. With the introduction of the modern coke blast furnace, their use was completely done away with. The deposits of titaniferous iron ores are so numerous, however, and some of them so large

[1] This paper, which is published with the permission of the Director of the U. S. Bureau of Mines, is a brief statement of the results of a metallographic study of the titaniferous magnetites of the United States. The more detailed presentation will form part of a report on the titaniferous iron ores of the United States to be published shortly as a bulletin of the Bureau of Mines. Since the results of this investigation afford another example of the possibilities of the metallographic method in dealing with the opaque ores, it has seemed desirable to present at this time a summary statement of them.

and so favorably located for cheap mining, that the hope of their ultimate utilization has never been given up. Experiments looking toward a method which would make their use possible have been conducted along various lines. One method that has repeatedly suggested itself is the elimination of the titanium by means of magnetic separation.

Magnetite is a highly magnetic mineral, ilmenite is but slightly magnetic or non-magnetic. If the titaniferous iron ores are mechanical aggregates of magnetite and ilmenite, it should then be possible to make a magnetic separation of the two minerals into concentrates consisting practically of pure magnetite and tailings which contain practically all of the ilmenite. Numerous attempts have been made to make such a separation of the ores, but with varying degrees of success. The results of such tests made by previous experimenters and by the author range from the most unfavorable case, in which the ratio of titanium to iron actually increased by 3 per cent., to the most favorable, in which that ratio was decreased by 97 per cent. It was further found that the finer the crushing to which the ore was subjected, the better the separation obtained. Experiments showed that while this is markedly true for the coarser sizes, a point is finally reached beyond which there is little gained by still finer crushing. The percentage of titanium removed at this stage ranged from 5 per cent. to 95 per cent. in the cases of those ores which were tested in this way.

The results of magnetic separation tests on titaniferous magnetites show, therefore, that to a certain but varying extent these ores consist of granular aggregates of magnetite and ilmenite. They also show that the magnetite grains of such aggregates to a certain, but varying, and in some cases to a considerable extent, carry titanium. The problem then presents itself of the manner in which this titanium occurs in the magnetite. Does it occur in the form of microscopic intergrowths of ilmenite in magnetite, or as an integral part of the magnetite molecule?

Here, again, a simple property in which the two minerals differ markedly makes possible the solution. Magnetite is easily solu-

ble in hydrochloric acid, whereas ilmenite is insoluble. By etching polished surfaces of the ore with hydrochloric acid, the relations between the two minerals, magnetite and ilmenite, are clearly brought out. Such surfaces consist of granular aggregates of magnetite and ilmenite, the ilmenite retaining the bright luster of its polish, whereas the magnetite has assumed a dull black appearance.

In most cases the relations between the ilmenite and magnetite grains are those of the constituents of a granular igneous rock. The texture varies from that of a fine-grained rock to that of a coarse-grained rock; the relative abundance of the two minerals ranges from ores in which the ilmenite is very subordinate in amount to ores in which the ilmenite greatly preponderates over the magnetite. The relative size of the grains of the two minerals is of nearly the same order of magnitude, though the ilmenite tends to average a little smaller than the magnetite. The most common shape of the grains is roughly equidimensional (Pl. III., *a*), but they also assume an elongate, and, especially in the case of the ilmenite, even a tabloid shape (Pl. III., *b*). The effect produced then is as if most of the elongated ilmenite grains followed the outlines of the magnetite grains with a few distinctly cutting across the latter.

If the dull black areas of magnetite are examined with the metallographic microscope, it is seen that they are not homogeneous, but contain minute intergrowths of ilmenite. The most common forms of ilmenite intergrowths in the magnetite are those which show in the sections as lines and as dots and each of these will be described separately, though in most instances both are present at the same time.

The lines are sections of minute ilmenite lamellæ oriented parallel to the octahedral faces of the magnetite. Hence in a simple magnetite crystal they can be oriented in three different planes, and in a twinned crystal in five different planes. In section, this may give rise to three series of parallel lines (Pl. III., *c*), or to five series respectively (Pl. III., *d*), as maxima; the actual number visible depends on the orientation of the section. The angles

EXPLANATION OF PLATES.

In all of the figures the white areas represent ilmenite, the black areas magnetite. Plate III, *a*, *b*, and Plate IV, *b*, *d*, are but slightly larger than natural size; all the others are microphotographs with an enlargement of 60 diameters.

PLATE III.

a. Granular aggregate of magnetite and ilmenite showing equidimensional grains.

b. Granular aggregate of magnetite and ilmenite, the latter showing a tendency to tabular grains.

c. Triangular network of ilmenite lamellæ in magnetite.

d. Network of ilmenite lamellæ in twinned magnetite crystal.

PLATE IV.

a. Prominent development of lamellæ in one direction only.

b. Tuscarora Mine ore showing ilmenite lamellæ visible to naked eye.

c. Protruberances characterizing lamellæ of Tuscarora Mine ore.

d. Poplar Lake ore showing ilmenite lamellæ visible to naked eye.

PLATE V.

a. Broken line effect of short lamellæ in one plane.

b. Unusually thick short lamellæ.

c. Crowded delicate lamellæ.

d. Abrupt termination of lamellæ with nearly barren area of magnetite beyond.

PLATE VI.

a. Shows series of large dots, and abundant minute dots which grade down to sizes too minute to show on photograph.

b. Rectilinear arrangement of large dots.

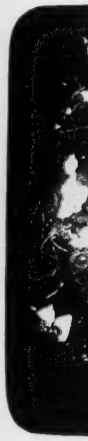
c. Rim of ilmenite about grains of ilmenite formed by coalescing of ilmenite particles which segregate in magnetite about periphery of ilmenite grains.

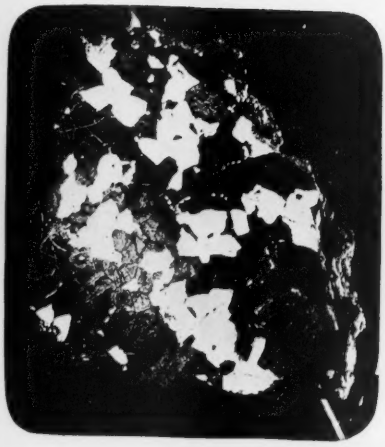
d. Thin film of ilmenite about outlines of magnetite grains.

PLATE VII.

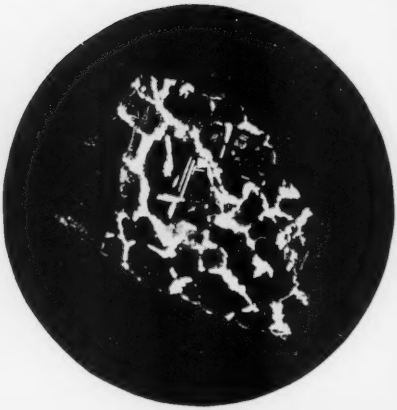
a. Crowding of ilmenite intergrowths about periphery of magnetite grains.

b. Lenticular bands of magnetite in ilmenite.





a

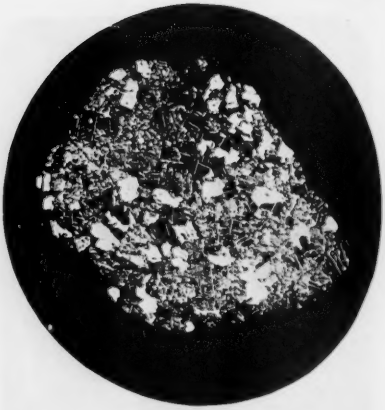


b

c

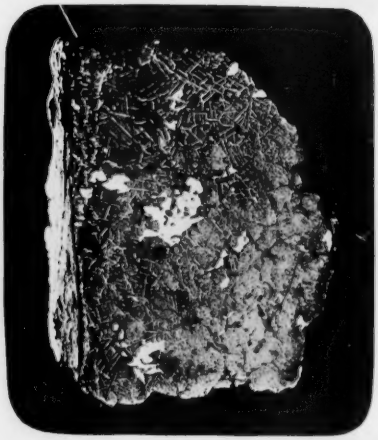
d

a



b

c

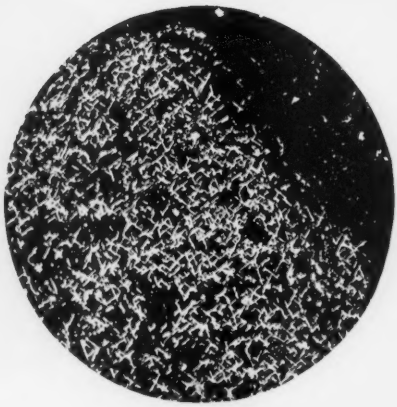


d

a

b

c



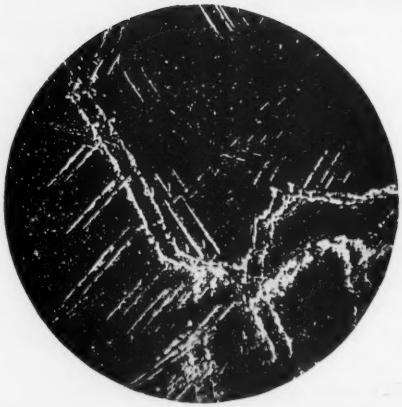
d

a

b

c

d



a

b

a. Crowding of ilmenite intergrowths about periphery of magnetite grains.
b. Lenticular bands of magnetite in ilmenite.

which the lines make with each other also depend on the orientation of the section. If the section lies parallel to the octahedral face, they intersect at 60°; as the section deviates from this position, the angles approach 0° on the one hand and 90° on the other. But even where the section is so oriented as to expose the three possible directions, intergrowths are not necessarily developed in all three, or at least not equally well developed. Thus the one series of lamellæ may be marked by heavy lines, whereas the other two are made up of very small, delicate lamellæ (Pl. IV., *a*). The pattern produced by the intersecting lamellæ may vary consequently from the equilateral triangular network of a simple magnetite crystal cut parallel to the octahedral face to the more complicated network of five series of intersecting lines in the case of twinned crystals or to the simplest case of one series of parallel lines.

In size the lamellæ range from such as are easily visible to the naked eye to lamellæ so minute as to be scarcely discernible under the highest magnification. The coarsest lamellæ in any of the ores examined by the author occurred in the ores of the Tuscarora mine in Guilford County, North Carolina (Pl. IV., *b*). These reach a length of 4 mm. and a thickness of .1 mm. They are characterized by local thickenings in the form of protruberances which have a thickness of as much as .2 mm. (Pl. IV., *c*). The plates are distinctly visible to the naked eye and may be peeled off cleavage faces of the magnetite with a knife edge. The only other lamellæ approaching these in coarseness were those in the Poplar Lake ore of Minnesota (Pl. IV., *d*). Aside from these exceptional cases, lamellæ having a length of 1 mm. and a thickness of .02 mm. must be regarded as unusually large and thick.

Generally, instead of one large continuous lamella, there are a number of smaller lamellæ in the same plane, so that in section the effect is that of a broken line instead of a continuous bright line of ilmenite (Pl. V., *a*). If unusually thick the short lamellæ may have a width of .02 mm. (Pl. V., *b*), but in most cases they are less than .005 mm. in thickness, and .001 mm. is not at all

uncommon. In length every size is represented from lamellæ so minute that their elongation is scarcely discernible to the larger lamellæ just spoken of.

As regards the number of lamellæ present there is also considerable variation. At times they are not very numerous and quite widely spaced, then again they are closely crowded (Pl. V., *c*). This crowding becomes in many instances closer and the lamellæ more delicate until the intersecting structure can no longer be made out and the magnetite has a peculiar bright luster, due to the almost continuous surface of ilmenite. Such grains can easily be distinguished from homogeneous ilmenite grains by the tendency of their luster to iridescence.

Not only does the number of lamellæ show great variation but also their distribution. One portion of the magnetite surface may be crowded with them, so that it shows a closely packed network, and another portion immediately adjacent thereto may be almost free of intergrowths (Pl. V., *d*). Then again lamellar intergrowths may suddenly terminate and dots occur in their place.

As common as the lamellæ is another variety of intergrowths which show in section as dots with approximately circular outlines. In size they show every gradation from the minutest to the largest, but the impression one receives is that they occur in groups of two sizes,—a larger size ranging from .05 to .01 mm. in diameter, and a smaller size ranging from about .002 mm. down to the smallest size observable (Pl. VI., *a*). Most commonly the dots are irregularly distributed over the magnetite surface, not showing any regular orientation. In some cases, however, they assume a rectilinear orientation parallel to the octahedral cleavages. This is especially prominent at times with the larger dots (Pl. VI., *b*). As regards quantity and evenness of distribution the same conditions exist as have been described for the lamellæ. The minute dots may be almost entirely lacking, or they may occur in such numbers as to form almost a continuous surface of ilmenite and produce the same peculiar luster of the magnetite that very closely crowded minute lamellæ cause.

In many of the ores there is a tendency for small granules of ilmenite to arrange themselves within the magnetite very close to its contact with an ilmenite grain. The granules are usually elongate and lie either with their longer axis parallel to the outline of the ilmenite grain, or at right angles to it. In most cases they form a discontinuous fringe about the ilmenite grains from which they are separated by a narrow zone of magnetite free of inclusions. Sometimes the granules coalesce, forming a continuous rim about the large ilmenite grain; and, if the elongate particles are oriented at right angles to the outline of the grain, the rim may attain a width of .2 mm. (Pl. VI., *c*). Besides these particles which tend to segregate along the contact with larger ilmenite grains, others of irregular to more or less circular shape are scattered here and there through the magnetite. The more common size of these is a maximum of .1 to .3 mm.

The magnetite grains are at times separated by a thin film of ilmenite, so that in section the outlines are marked by a bright rim of ilmenite (Pl. VI., *d*). Somewhat analogous to this is the crowding of regular intergrowths along definite lines in the magnetite areas which are often the periphery of the grains (Pl. VII., *a*).

One other form of intergrowth was found in two Canadian ores. It consists of numerous narrow lenticular bands of what seems to be magnetite, though not as readily acted on by the acid as mangetite usually is, intercalated in grains of ilmenite (Pl. VII., *b*). The structure would suggest the solidification of a magnetite-ilmenite eutectic, and is worthy of further investigation.

The ilmenite intergrowths which have just been described are too minute to admit of a mechanical separation from the magnetite. In many cases they are abundant enough to give the magnetite a considerable titanium content, and this accounts to a large extent for the failure of magnetic separation to eliminate the titanium from the ores.

The question still remains open at this point, whether any of the titanium occurs as a part of the magnetite molecule. To an-

swer this question particles of magnetite were carefully picked from grains of magnetite showing no ilmenite intergrowths and etching with a uniform dull black surface. An analysis of these particles showed a titanium content of 6.6 per cent. This result would tend to prove the existence of a mineral, titano-magnetite.

RESUME.

Titaniferous magnetites consist of granular aggregates of magnetite and ilmenite. The magnetite is usually not homogeneous, but contains minute intergrowths of ilmenite in both regular and irregular orientation and may contain a considerable percentage of titanium in the magnetite molecule itself. The relative percentages of the titanium content of these magnetites occurring in these three different forms are subject to variation between wide limits.

A REVIEW OF THE EXISTING HYPOTHESES ON THE ORIGIN OF THE SECONDARY SILICATE ZONES AT THE CONTACTS OF INTRUSIVES WITH LIMESTONES.

PART II.[1] PHYSICS AND CHEMISTRY OF THE CONTACT ZONES AND CONCLUSIONS.

W. L. Uglow.

III.

COMPARISON OF ANALYSES OF FRESH AND ALTERED LIMESTONES BY MEANS OF THE COMPOSITE STRAIGHT-LINE DIAGRAM.

It is a very difficult matter to make a correct statement offhand as to whether or not a bed of limestone contains impurities enough and in the right proportions to afford lime-alumina and other silicates on recrystallization. Even a chemical analysis of a typical specimen of the fresh limestone is by no means a sufficient foundation on which to base such a statement. Only careful sampling of the fresh and altered rocks, and a comparison of their compositions on a rational basis of comparable samples, can show whether or not the "secondary silicate zone" may be merely the result of redistribution and recrystallization of the original constituents of the limestone.

In very few cases, indeed, has this method been followed. The only fruitful sources of information with regard to specific contact-zones are papers and reports dealing with western mining camps. A great deal of the field work was undertaken by consulting geologists and geologists from the United States Geological Survey; and the problem of the origin of the "secondary silicate zones" was necessarily relegated to the position of a side-issue. The amount of investigation and sampling required to reap many useful results in this regard could not be devoted to

[1] Part I. of this article appeared in Economic Geology, Vol. VIII., No. 1. pp. 19–50.

that particular phase, and hence the conclusions of these geologists may not have been based on all the pertinent data.

The authors of the U. S. G. S. publications referred to, especially those dealing with the western camps, have been too prone to state that the limestone beds now "replaced" by silicates were too pure originally to afford these results of themselves. Careful reading of their own discussions of the stratigraphic column will show that even in the very horizon of the ore bodies, the limestone is not pure calcium carbonate.[1] In the very nature of the case, it is difficult to conceive of beds of limestone of any thickness, absolutely free of chert, sand, or clay, to say nothing of iron oxide, and the carbonates of iron and magnesium. In most of the contact camps the limestones are interbedded with sandstones, quartzites, shales, graywackes, dolomites, etc., and in several cases there are all gradations between them.

In making a comparison of the chemical compositions of the unaltered and metamorphosed rocks, it is of the first importance to remember that *average* samples should be compared with each other. The "secondary silicate zone" in nearly all cases is composed of three or more minerals—garnet, epidote, tremolite, quartz, calcite, etc. A comparison of one or two samples of the mineral garnet with one or two samples of a pure limestone, not from the same horizon, such as Kemp[2] has made, gives results of little value. Lindgren,[3] again, states that the andradite garnets of the contact-zones in the Clifton-Morenci camp contain more iron than could be derived from the limestone. His conclusion is invalidated because comparable average samples should alone be used. It is the average chemical composition of the rock of the "secondary silicate zone" and not of one mineral, that should be compared with that of the sedimentary series of the same horizon. Such minerals and phases of metamorphism as are produced during the second or metasomatic stage of contact action should of

[1] Kemp and Gunther, *A. I. M. E.*, XXXVIII., p. 276; F. L. Ransome, Prof. Pap. 21, p. 55; W. Lindgren, Prof. Pap. 43, p. 71.

[2] J. F. Kemp, "Ore Deposits at the Contacts of Intrusive Rocks and Limestones," ECON. GEOL., Vol. II., No. 1, p. 1, 1907.

[3] W. Lindgren, U. S. G. S., Prof. Pap. 43.

course be eliminated from the sample which represents the average altered rock to be used in comparison with the fresh rock. Too much care cannot be exercised in the selection of samples, and the averages in each case should be weighted ones.

A. Iron Springs, Utah.

	No. 1.	No. 2.	No. 3.
SiO_2	8.08	52.00	15.5
Al_2O_3	1.95	9.32	20.9
Fe	0.66	5.43	12.1
MgO	2.86	9.40	30.4
CaO	46.67	14.47	322.0
Na_2O	0.13	1.94	6.7
K_2O	0.77	1.41	54.5
H_2O+	1.01	3.30	30.6
CO_2	37.60	0.63	5,975.0

No. 1 = Unaltered blue limestone.

No. 2 = Altered limestone near andesite intrusive.

$$\text{No. } 3 = \frac{\text{No. } 1}{\text{No. } 2} \times 100.$$

Reference: Bull. U. S. G. S., 338, pp. 26–27.

B. Hastings County, Ontario.

	No. 1.	No. 2.	No. 3.
SiO_2	33.02	51.75	63.8
Al_2O_3	9.08	18.98	47.9
Fe	3.25	6.78	47.9
MgO	4.20	4.98	84.4
CaO	31.02	7.63	406.8
Na_2O	1.17	4.30	27.2
K_2O	0.85	1.86	45.7
H_2O+	1.08	1.42	76.1
CO_2	15.27	0.11	13,890.0

No. 1 represents the first stage of alteration from a limestone. Recalculation of No. 1 (*a*) (Adams) after eliminating TiO_2.

No. 2 = Altered (amphibolite). Recalculation of No. 3 (Adams) after eliminating TiO_2, S, MnO, Cl.

$$\text{No. } 3 = \frac{\text{No. } 1}{\text{No. } 2} \times 100.$$

Reference: F. D. Adams, *Jour. Geol.*, XVII., No. 1, 1909.

After a somewhat diligent search of the literature, and through the kindness of W. J. Mead, of the department of geology of the

University of Wisconsin, analyses of fresh and altered limestones were obtained from the following camps: Iron Springs, Utah; Hastings County, Ontario; Bingham, Utah; Bisbee, Arizona; White Knob, Mackay, Idaho; Chanacillo, Chile; San Jose, Tamaulipas, Mexico; Clifton-Morenci, Arizona. In all cases but the first two the analyses are incomplete; and without any exception, they are not based on average samples. Nevertheless, they afford the best available quantitative data, and as such they may give some valuable suggestions. Averages were struck by the writer from the analyses where it seemed advisable, and the respective quotients were platted on the composite straight-line diagram on page 219 (Fig. 12).

C. BINGHAM, UTAH.

	No. 1.	No. 2.	No. 3.
SiO_2	12.50	50.41	24.8
Al_2O_3 } Fe_2O_3 }	1.99	0.80[1]	(249.0)
MgO	3.66	24.57	14.9
CaO	48.34	9.74	483.0
H_2O+	4.31	11.81	36.5
CO_2	28.06	1.61	1,740.0

No. 1 = Fresh gray limestone (Old Jordan mine).
No. 2 = Altered limestone (white marble with little tremolite).
No. 3 = $\frac{\text{No. 1}}{\text{No. 2}} \times 100$.
Reference: U. S. G. S., Prof. Pap. 38, p. 191.

Figure 12 is constructed in accordance with a method used in the metamorphic laboratory of the University of Wisconsin, and described by W. J. Mead[2] in a recent number of ECONOMIC GEOLOGY. It is simply a convenient graphic method of representing the changes in chemical composition which a rock undergoes during alteration. The division of the percentages of the constituents in the fresh rock by the percentages of the respective constituents in the altered rock gives a series of ratios which show at a glance how the different oxides have acted with respect to each other. Although the analyses themselves might be

[1] Only very approximate. Spoils value of quotient. (Not platted.)
[2] W. J. Mead, "Some Geologic Short-Cuts," ECON. GEOL., VII., No. 2, 1912, pp. 143–144.

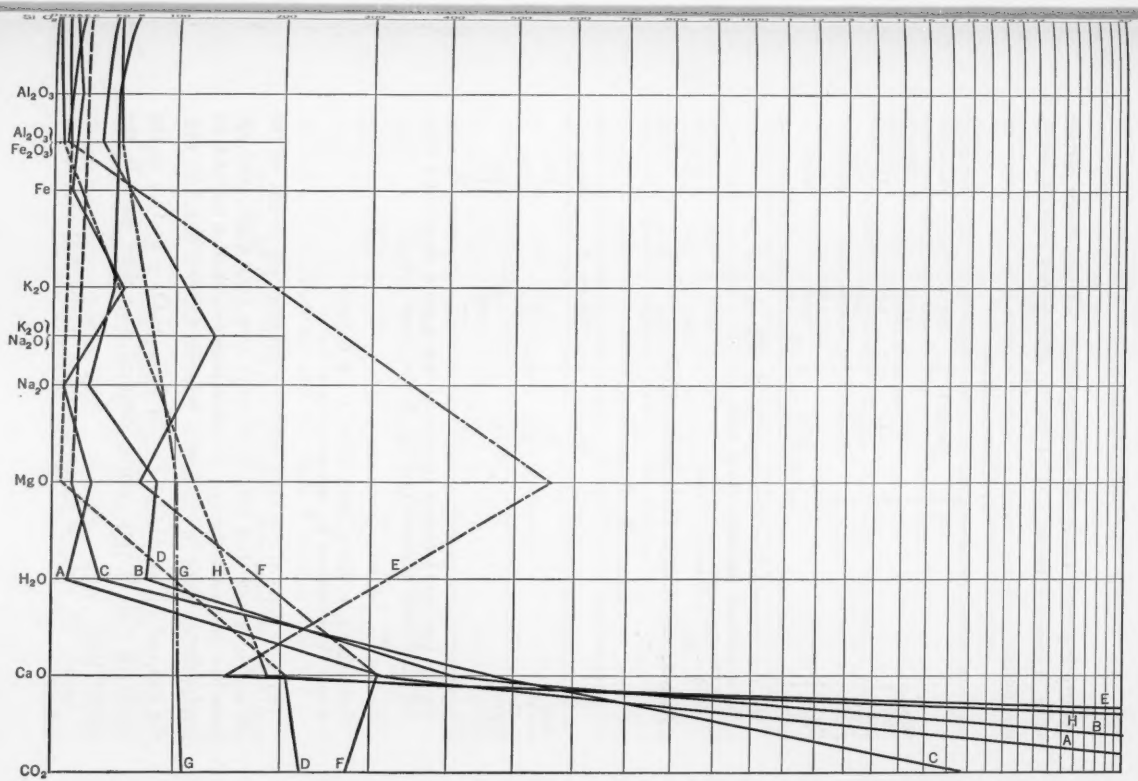


FIG. 12. Composite straight-line diagram, *A*, Iron Springs, Utah; *B*, Hastings-Grenville, Ont.; *C*, Bingham, Utah; *D*, Bisbee, Arizona; *E*, White Knob, Idaho; *F*. Chanacillo, Chile; *G*, San Jose, Mexico; *H*, Clifton-Morenci, Ariz.

greatly improved upon, the platting shows without doubt certain very significant tendencies at work, during the contact metamorphism:

D. Bisbee, Arizona.

	No. 1.	No. 2.	No. 3.
SiO_2	2.52	28.55	8.8
Al_2O_3 } Fe_2O_3 }	0.24	2.16	11.1
MgO	0.76	13.62	5.6
CaO	53.68	26.20	205.0
H_2O+		3.08	
CO_2 }	43.07[1]	19.00	227.0
FeS_2		5.63	

No. 1 = Unaltered Naco limestone (III., p. 148).
No. 2 = Altered limestone (I., p. 148).
No. 3 = $\frac{\text{No. 1}}{\text{No. 2}} \times 100$.
Reference: U. S. G. S., Prof. Pap. 21, p. 148.

E. White Knob, Idaho.

	No. 1.	No. 2.	No. 3.
SiO_2	8.07	37.43	21.5
Al_2O_3 } Fe_2O_3 }	2.34	29.08	8.0
MgO	2.44	0.44	555.0
CaO	47.23	32.67	144.2
CO_2	39.72	——	∝

No. 1 = Unaltered limestone (average of Nos. 1 and 2, bottom of p. 6).
No. 2 = Altered limestone (average of Nos. 4 and 5, p. 7).
No. 3 = $\frac{\text{No. 1}}{\text{No. 2}} \times 100$.
Reference: J. F. Kemp, Econ. Geol., II., p. 6, 1907.
Note.—These analyses are not comparable.

(*a*) The slope of the lines joining corresponding points on the SiO_2, Al_2O_3 and iron lines is in every case very slight, and approaches perpendicularity. In accordance with the method of interpretation used in the article referred to, this indicates that the ratio of SiO_2: Al_2O_3: Fe (or SiO_2:$\overline{Al_2O_3 + Fe_2O_3}$) in the unaltered rock is very nearly identical with their ratio in the altered type.

[1] Enough CO_2 added to partial analysis to change MgO and CaO to carbonates.

F. CHANACILLO, CHILE.

	No. 1.	No. 2.	No. 3.	
SiO_2.....	22.82	47.97	47.6	No. 1 = Unaltered limestone.
Al_2O_3 } ..	3.53	10.12	34.9	No. 2 = Altered limestone.
Fe_2O_3 }				
MgO.....	11.46	16.71	68.5	No. 3 = $\frac{\text{No. 1}}{\text{No. 2}} \times 100$
CaO.....	29.73	9.65	308.0	
Na_2O } ...	1.69	1.27	133.0	
K_2O }				
CO_2.....	31.09	11.64	274.0	

Reference: Natur Marburg, 1870, p. 26.

G. SAN JOSE, MEXICO.

	No. 1.	No. 2.	No. 3.	
SiO_2.....	4.67	9.55	48.9	No. 1 = Fresh limestone (average of (1) and (2), Kemp).
Al_2O_3 } ..	0.65	1.28	50.8	
Fe_2O_3 }				
MgO.....	0.44	0.43	102.0	No. 2 = Crystalline limestone (analysis No. 3, Kemp.)
CaO.....	52.70	49.79	101.0	
CO_2.....	41.98	39.61	105.9	No. 3 = $\frac{\text{No. 1}}{\text{No. 2}} \times 100$.

Reference: J. F. Kemp, ECON. GEOL., II., p. 6, 1907.

H. CLIFTON-MORENCI, ARIZONA.

	No. 1.	No. 2.	No. 3.	
SiO_2.....	1.13	39.45	2.9	No. 1 = Average fresh Modoc limestone.
Al_2O_3 } ..	1.76	33.42	5.3	No. 2 = Average garnet (andradite).
Fe_2O_3 }				
MgO.....	1.62	?	?	
CaO.....	50.80	26.52	192.0	No. 3 = $\frac{\text{No. 1}}{\text{No. 2}} \times 100$.
CO_2.....	41.66	——	∞	

The analysis of the fresh rock is only partial. The analysis of the altered phase is only of garnet. No account is taken of the other silicates.

Reference: U. S. G. S., Prof. Pap. 43, p. 71.

(*Note.*—In the diagram, where the analyses were sufficiently complete so that points were obtained on adjacent horizontal lines, these points are connected by full lines. When, however, no point was obtained on a certain line, the line joining the points on the lines above and below is broken.)

(*b*) The slope of the lines joining CaO, CO_2 and H_2O shows that there has been a relatively very great loss of CO_2, and a considerable relative loss of CaO. The slope of the lines joining CaO and CO_2 is evidence of the dissociation of part of the cal-

cium carbonate, and of the loss of CO_2 in the form of carbon dioxide. Since CaO is also lost relatively to SiO_2, Al_2O_3, and Fe, it is quite probable that much of the calcium carbonate was volatilized and driven off without dissociation.

The interpretation of these facts accords well with the hypothesis of the recrystallization of the original constituents of the limestone to form the "secondary silicates." It would be rather a difficult proposition to account for the approximate constancy of the silica-alumina-iron ratios by any theory of their introduction. If the ratios were nearly constant in only one case, and were quite different in the majority of cases, there would be but little difficulty about attributing the matter to mere coincidence. But in seven out of the eight examples, which seem to constitute at present all the available data, the ratios are found to be very nearly constant. It would be a remarkable coincidence, indeed, if the silica, alumina, and iron were each time added in almost exactly the same ratio as that in which they were present in the unaltered rock. In this connection it is instructive to note that the amounts of silica, alumina, iron oxides, etc., present in the fresh limestone depend *not* on silicate ratios, but upon the abundance of chert, kaolin, iron and magnesium carbonates, etc. By far the most reasonable explanation of this one feature is that the actual masses of these constituents varied but slightly during the alteration, but that the substances present in great excess were expelled, thus raising the percentages of those oxides in the rock.

If it be granted that there is about the same absolute amount of silica, alumina, and iron in the altered as there was in the fresh rock, a very great reduction in volume of the sediments must be accounted for. This state of affairs seems to be quite plausible for two reasons: in the first place there is, so far as known, scarcely anything in the density, texture, or structure of the contact phase to tell what proportion of the original volume of the limestone it represents. Two cases are cited in the tabulation above, in which reduction of volume is indicated by a dip of the limestone beds toward the Black Butte stock,[1] and by a crumpling

[1] W. H. Weed and J. Barrell, "Geology and Ore Deposits of the Elkhorn Mining District, Montana," U. S. G. S., 22d Ann. Rept., Part II., p. 444.

of interbedded gneisses in the Adirondack region.[1] In the second place, when a great batholith begins an upward journey, it makes way for itself in a manner not yet clearly understood—by marginal assimilation, by crowding the adjacent rock aside through faulting and folding, by overhead stoping, by eliminating easily soluble constituents in the wall rock, or by some combination of these processes. A reduction of volume of, say, 80 per cent. by contact metamorphism could be easily obscured by the advance of the batholith. To quote here from C. K. Leith,[2] in reference to the Iron Springs district: "As one stands on the edge of one of the large laccoliths in this district and is asked whether the 60-foot silicated phase represents an original 300 feet or original 80 or 90 feet, the difference linearly is so small as to have little effect on one's judgment."

There is a tremendous loss of carbon dioxide under any hypothesis. It does not seem probable that this loss should be made good by an introduction of new material, when the natural tendency is toward contraction of volume due to increased pressure, rather than that recrystallization and structural changes should obscure the evidences of contraction and incidentally afford space for the intrusive.

IV.

THE BEARING OF SOME PRINCIPLES OF PHYSICAL CHEMISTRY ON THE FORMATION OF THE "SECONDARY SILICATE ZONES."

With regard to the reactions that might take place between $CaCO_3$, SiO_2, kaolin, and H_2O under conditions of temperature and pressure such as exist at limestone contacts, very little is definitely known. Some experimental work, however, has been done that may have an important bearing on the problem. Several investigators have dealt with the subject of the dissociation of calcium carbonate. J. Königsberger[3] published a table show-

[1] C. H. Smith, Jr., "Rocks of the Northwestern Adirondack Region," *Bull. Geol. Soc. Am.*, Vol. VI., p. 265, 1894.

[2] C. K. Leith, "Iron Ores of Iron Springs District, Utah—Reply to Review by J. F. Kemp," ECON. GEOL., Vol. V., 1910, p. 188.

[3] J. Königsberger, *N. J. Blgbd.*, XXXII., 1911, pp. 101–133.

ing the temperature-pressure relations for the dissociation of calcium carbonate to lime and carbon dioxide. He finds that for a temperature of 1,400° C. a pressure of 80,000 atmospheres or 1,200,000 pounds per square inch is required to prevent the reaction. This pressure would involve a depth of about 20 miles. From this he argues that the presence of calcium carbonate as an inclusion or in contact with the magma is a safe maximum geological thermometer. Le Chatelier[1] also gives a table of the same temperature-pressure relations, but he deals with lower pressures. He finds that a temperature of 812° C. is sufficient to develop a pressure of one atmosphere. This is 78° lower than the figure given by Königsberger. Both of these experimenters worked under dry conditions. By taking average values for rock density and applying the results of these physicists, it is found that calcium carbonate existing at depths of 1,000 feet and 2,000 feet could only be dissociated at such temperatures as 1,150° C. and 1,200° C. respectively. Only rarely, if at all, are temperatures of this magnitude produced in the intruded rocks at such shallow depths.

It is evident, therefore, that some other factor must be very important. This is probably the presence of impurities such as silica, kaolin, and water. Gay-Lussac[2] makes the following statement: "Un courant d'air ou de vapeur d'eau facilite la décomposition du $CaCO_3$, ce qui s'explique par l'élimination continue du gaz carbonique dégagé." Jacquelain[3] finds that "à 100° C. en presence d'eau, la dissociation est déjà sensible." According to Bischof[4] "when water is distilled over mixed carbonate of lime, magnesia, or spathose iron, with artificially prepared silica or powdered quartz, carbon dioxide passes over with the aqueous vapor." Such results as these indicate that the presence of kaolin and chert or quartz in limestone would greatly lower the temperature at which the lime-silicates would be formed. There are still at least two unknown factors in this reaction as it would take

[1] Le Chatelier, *Compt. Rend.*, Vol. 102, pp. 1,243, 1886.
[2] Gay-Lussac, *An. Ch. Ph.* (2), 63, 219, 1836.
[3] Jacquelain, *Compt. Rend.*, 30, 106, 1850.
[4] Bischof, "Chemical and Physical Geology," Vol. I., p. 7.

place in nature. In the first place, there is the effect of pressure on the temperature at which the reaction would occur. A calculation of molecular volumes in the reaction shows very little change, so it is probable that increase of pressure will not have a great effect. In the second place, there is the presence of such materials as Al_2O_3, $MgCO_3$, Fe_2O_3, etc. No data are at hand by which their influence could be estimated. All that can be said is this—the presence of water and silica and probably other impurities seems to lower the temperature at which dissociation of calcium carbonate and the formation of lime-silicates may take place.

In order that complete dissociation of $CaCO_3$ under conditions of contact metamorphism may be accomplished, a means of escape must be provided for the carbon dioxide. This may be explained by the following quotation from J. V. Elsden:[1] "At 812° C. the dissociation pressure of $CaCO_3$ is equal to one atmosphere. At this temperature, therefore, $CaCO_3$ can be completely dissociated in presence of CO_2 at atmospheric pressure. By increasing the pressure until the partial pressure of the CO_2 exceeds the dissociation pressure of $CaCO_3$ the latter does not dissociate, whatever may be the temperature to which it is exposed. It is important to note that this result depends upon the condition that the products of the reaction are not removed from the sphere of action. If the CO_2 is removed as fast as it is formed, dissociation can proceed at a far lower temperature since the dissociation equilibrium of the carbonate depends not upon the pressure to which it is subjected, but upon the partial pressure of the CO_2 in contact with it." Hence, as long as the CO_2 can be carried away so as to keep its partial pressure below the dissociation pressure of the carbonate, dissociation will continue to take place.

The above principle must have very important applications to the problem in hand, but it is almost impossible to approximate to these applications without a better knowledge of the actual conditions. In the different limestone contacts all degrees of

[1] J. V. Elsden, "Principles of Chemical Geology," p. 76.

partial dissociation are found. The amount of unaltered carbonate present varies from zero in some places to a considerable amount in others. This variation is no doubt partially due to the facility for escaping which the structural conditions after the intrusion gave to the carbon dioxide. There is a wide and interesting field of investigation in this very connection, but the data that are so far available are by no means adequate.

A clue might possibly be obtained as to whether or not fractures were present in the neighborhood of the magma at the time of its intrusion, by a study of rock structures and textures. If the age of the intrusion were definitely known a completely restored section of the intruded rocks might be made, although it would be on a rather ideal basis. This has been done in a few cases, and the depth of covering which lay over the cooling magma estimated. In each case, as the writer remembers, the intrusion took place distinctly into the zone of rock fracture. Means of escape for the dissociated CO_2 would then have been readily afforded.

Other suggestions might be afforded by a study of the textures of the igneous rock—whether phaneritic, porphyritic, or aphanitic. A coarse-grained rock evidently crystallizes very slowly, and therefore under a great depth of cover. Whether this depth is great enough to relegate the intrusion to the zone of flowage depends on the actual conditions in each case. A porphyritic rock, with a fine-grained matrix, must have been either intruded into cold rocks, or into hot rocks when it was very close to its point of crystallization. An aphanitic rock suggests very rapid cooling and a proximity to the surface.

There is another quite different aspect of the "secondary silicate zones" that is worthy of serious consideration. What is the connection between the chemical composition and texture of the igneous rock, and the character and extent of its metamorphic action? There are acidic rocks, ranging in texture from plutonic to felsitic, and there are basic rocks with all variations from plutonic to basaltic. A perusal of the literature reveals an apparent genetic connection of some sort. Basic rocks do not as a rule

produce as great a contact zone as acidic rocks. Ransome,[1] in his report on the Globe Copper District, Arizona, makes the following statement: "The metamorphic action of the diabase, even when intruded in great masses into quartzites and limestones, is remarkably slight. The only effect discoverable in the Globe limestone is the development of a little coarser crystalline texture which may extend for only a few inches from the contact." Lindgren[2] states in his report on the Clifton-Morenci District that "while the diorite-porphyries have changed the surrounding sedimentary beds but little by the heat and emanations of the magma, the quartz-monzonite-porphyries have generally exerted a profound alteration, especially in the Paleozoic limestones and shales." Kemp[3] and other advocates of the direct introduction hypothesis use such facts as these to support their position. They relate the extent of the contact zone to the quantity of emanations proceeding from the magma. R. T. Chamberlin[4] has shown that basic rocks contain more gases than acidic ones, and volcanics more than plutonics. From this it is argued that coarse-grained acidic rocks give off a greater quantity of gases on crystallization. Again, it is known that the minerals characteristic of acidic rocks are "low-temperature minerals,"[5] that is, minerals that crystallize from fusion only with the aid of water, or other fluxes, solvents, or special reagents. Acidic magmas, then, before crystallization are well provided with mineralizers. These must be freely given off on crystallization. A very striking case, however, of an extensive contact zone around basic intrusives is seen in the Lake Superior district, where the Duluth gabbro intrudes the iron formation sediments, converting them into amphibole-magnetites, jaspilites, and hard ores.

From the point of view of the recrystallization hypothesis, it is admitted that these mineralizing gases play an important part in the formation of the second phase of the metamorphic zone,

[1] F. L. Ransome, U. S. G. S., Prof. Pap. 12 (pp. 85–86).
[2] W. Lindgren, U. S. G. S., Prof. Pap. 43 (pp. 85, 126).
[3] J. F. Kemp, "Types of Ore Deposits."
[4] R .T. Chamberlin, "Gases in Rocks," Publication 106, Carnegie Institution of Washington, 1908.
[5] A. Harker, "The National History of Igneous Rocks," p. 284.

but it is maintained that this period of emission is decidedly later than that of the formation of the first phase. It remains, then, to correlate the extent of this phase, not to the quantity of mineralizers given off by the intrusive, but to the temperature and pressures at which the different magmas crystallize, and to the nature of the intruded sediments. Sufficient data have been cited to show that the formation of the silicates is genetically related to the presence of impurities in the limestone; but at present it would be difficult to establish such a connection between the zones and the temperatures of crystallization of the intrusives.

V.

A STUDY OF THE HEAT CONDITIONS ACCOMPANYING AN INTRUSION.

A new feature enters the problem when the time element is considered in connection with the transfer of heat. It has been commonly conceded that the formation of the contact zones is not the affair of a moment, but it is scarcely wrong to say that no adequate estimate of the length of time during which a difference of temperature between intruded and intrusive rocks is sustained has yet been made. No such estimate, at least, appears in the literature.

Some very interesting results based on calculations of this nature have been kindly given to the writer by Dr. L. R. Ingersoll, of the physics department of the University of Wisconsin. Owing to the impossibility of getting data, at present, as to the specific heat, density, and thermal conductivity at the temperatures of intrusive magmas, the results can necessarily be only approximations. Allowing for transfer of heat by conduction alone, and making probable corrections in the different factors for the high temperature of magmas, a result such as that given below would be obtained. Considering that the temperature of the granite at the beginning was 1000° C., and that of the limestone 100° C., the application of the following formula will

give a temperature of the bounding plane between 690° C. and 755° C.

$$\theta = \left\{ \frac{K_1\theta_1}{h_1} + \frac{K_2\theta_2}{h_2} \right\} \Big/ \left\{ \frac{K_1}{h_1} + \frac{K_2}{h_2} \right\}$$

where θ = temperature of bounding plane in ° C.,
K_1 = conductivity of granite at ordinary temperatures = 0.0081,
h_1 = diffusivity of granite at ordinary temperatures = $\sqrt{0.0155}$,
θ_1 = temperature of magma in ° C.,
θ_2 = temperature of limestone in ° C.,
K_2 = conductivity of limestone at ordinary temperatures = 0.0050,
h_2 = diffusivity of limestone at ordinary temperatures = $\sqrt{0.0092}$.

In order to get limiting values for θ, the following alterations were made in the values of K_1 and h_1:

(1) $\begin{cases} K_1 \text{ was multiplied by 3, and} \\ h_1^2 \text{ was multiplied by 2.} \end{cases}$

(2) $\begin{cases} K_1 \text{ was multiplied by 1.5 and} \\ h_1^2 \text{ was multiplied by 1.} \end{cases}$

It seems quite certain, therefore, that the temperature of the boundary plane should lie somewhere between the two results obtained. A very important modification of the result will be obtained when allowance is made for the transfer of heat by convection currents, from the interior to the periphery of the igneous mass. By this means, the temperature at the contact will be maintained somewhat near that in the interior. The temperature of the boundary plane given above will therefore be too low, and it is not improbable that something like 900° or 950° may be reached.

The rate at which heat is transferred from the hot to the cool rock is far more important than the actual temperature at the

contact. The following diagram has been constructed by Dr. L. R. Ingersoll to represent the rate of advance of the heat wave through average rocks. The factors used in the calculation were

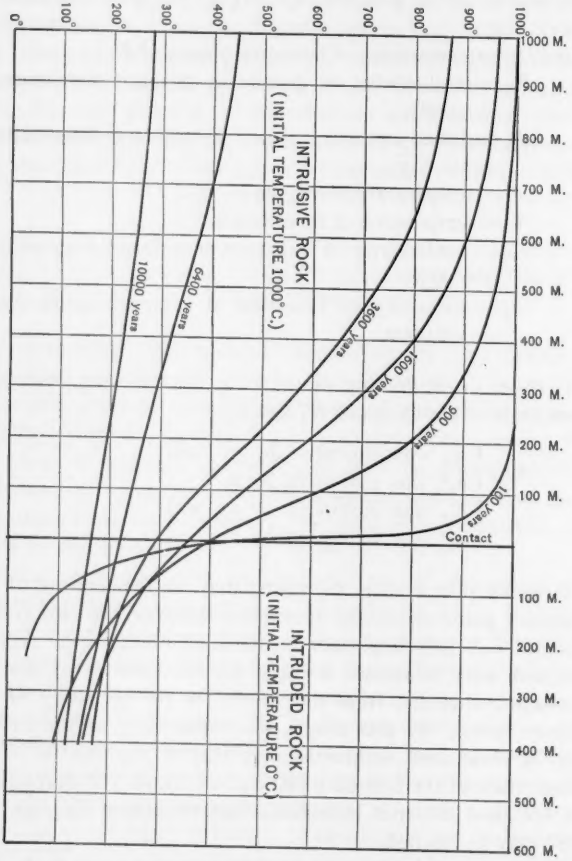


FIG. 13. Diagram showing progress of heat waves from a cooling laccolith 1,000 meters in radius, with initial temperature of 1000° C.

average ones, and little allowance was made for the different character of the two rocks. Nevertheless, the results are very interesting and important. They show that under those conditions a difference of temperature of about 50° C. still obtains between points two hundred meters on either side of the contact, ten thousand years after the intrusion.

No doubt, corrections to be made for the different characters of the rocks, and allowance for convection in the magma would substantially change the position of the curves, but it is unlikely that the amount of time required to produce equality of temperature in both rocks would be materially altered. This factor of time is the important one geologically.

INTERPRETATION AND RESULTS.

From Fig. 13 it is evident that the limestone for considerable distances from the contact receives a marked accession of heat from the intrusive. With the gradual advance of the magma, the outer edge of the heated zone maintains a position at a considerable distance within the limestone. Due to this rise of temperature, and to pressure exerted by the intruding magma, the limestone must necessarily be under a great degree of compression. Provided the pressure is not too great, the high temperature will cause the dissociation of the calcium carbonate, and the formation of lime silicates. The pressure will constantly tend to diminish the volume, and to eliminate pore space during the process of recrystallization.

Each zone in the limestone, parallel to the contact, will experience a continuous rise of temperature, until a maximum is reached. Subsequent to this, a cooling will set in, accompanied by a contraction of the hot limestone. As this cooling and consequent contraction proceed, tension fractures will develop, and these may give rise in the later stages to persistent fissuring. During this stage of the contact action, the emission of mineralizing solutions from the magma will be most abundant, and in the natural course of events they should deposit their load in the fissures and small openings thus afforded, and replace the pre-

viously metamorphosed limestone in the walls. For each particular zone in the limestone these two stages of recrystallization, and infiltration of pneumatolytic constituents, are sharply differentiated in time; but it must be noted that while the limestone at a considerable distance from the intrusive is in a state of rising temperature and compression, that near the intrusive may have already passed the maximum and be in a condition where fissures are developing.

The recent paper by Spurr, Garrey, and Fenner[1] on the Matehuala District, Mexico, affords data which go far towards validating this course of reasoning. These geologists actually find that the first structural effect of the intrusion on the limestone was a shattering and recrystallization due to increased pressure, and that it was followed later by the gradual development of persistent fissures, which are filled by a series of the younger minerals.

There is another fact that is rendered exceedingly important by the discovery that the length of time during which there is a difference of temperature between the limestone and the igneous rocks is not a matter of a few years, but rather of thousands of years. This new factor is the activity of the underground circulating waters. While the intrusive is still hot, there is abundant opportunity for the waters to work it over and leach from it metallic and other constituents, which might later be deposited in other parts of the intrusive or in the "secondary silicate zone" of the limestone. This interpretation is practically the same as Lawson's hypothesis of the disturbance of the underground water, with the exception, of course, that Lawson does not allow of the formation of the "secondary silicates" by heat and pressure alone, but attributes the formation of the whole zone to the one cause.

If the above suggestion as to the work of heated underground (both meteoric and magmatic) waters be correct, a considerable burden of work formerly attributed to magmatic emanations is shifted to another agency.

[1] Spurr, Garrey, and Fenner, "Study of a Contact Metamorphic Ore-Deposit. The Dolores Mine, at Matehuala, S. L. P., Mexico," ECON. GEOL., Vol. VII., p. 444.

The balance of evidence consequently seems to be quite in favor of the origin of the "secondary silicate zones" by the elimination of excess $CaCO_3$, and the recrystallization of the impurities into lime silicates. Of course, there are many features of contact zones described from the different camps that do not seem to be in harmony with the hypothesis, but such discrepancies may be largely due to the personal equation which inevitably influences observations and inferences.

Acknowledgments are especially due to Dr. C. K. Leith, and Mr. W. J. Mead, of the University of Wisconsin, for the interest they manifested, and the assistance they gave during the preparation of this paper.

Appended is a complete bibliography of the references used in the preparation of the paper, which have not previously been given.

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THE HOT SPRINGS AND THE MINERAL DEPOSITS OF WAGON WHEEL GAP, COLORADO.[1]

W. H. Emmons and E. S. Larsen.

INTRODUCTION.

Wagon Wheel Gap is in Mineral County, southwestern Colorado, near the border of the great group of mountains which collectively are termed the San Juan. It is about seven miles southeast of Creede, a mining camp that is well known on account of its production of precious metals, lead, and zinc. The Gap is a narrow pass, the result of erosion by the Rio Grande River that cuts through a relatively resistant ledge of igneous rock at this place. The hot springs are on Goose Creek, about one mile south of Wagon Wheel Gap. The relief of the country is high and the climate somewhat moist. Before the mines of Creede were discovered this resort was the terminus of the Denver and Rio Grande Railroad.

These springs are well known throughout the west for their curative powers, and have been in great favor ever since the country was settled. Indeed, it is said to have been a custom of the Ute Indians, who held sway in this country as late as the sixties, to make pilgrimages to the springs to bathe in their healing waters. Today numerous lodges, a modern hotel, and handsome bath house accommodate those who visit this beautiful resort.

The following notes are the result of a few hours' study by the writers, who made a hasty visit to the springs incidental to an investigation of the geology and ore deposits of Creede. The rocks are entirely of igneous origin, and, so far as known, are intrusive and belong to the Potosi Volcanic Series of Miocene age. There was not sufficient time to study the geology in detail, but the rocks are known to correspond to those at Creede, Colo.,

[1] Published by permission of the Director of the United States Geological Survey.

and particularly to the divisions that there are termed the lower rhyolite, the lake beds, and the latite of McKenzie Mountain.[1] The presence of the two surfaces of very marked irregularity which separate the different divisions of the volcanic rocks, together with the great complexity of the rocks themselves, has made it impossible to determine the presence or absence of faulting from a hasty study of a small area.

Mr. Larsen has studied in some detail the area to the west of Hot Springs and there the lower slopes of the valley of the Rio Grande and of Goose Creek are made up chiefly of tuff beds and

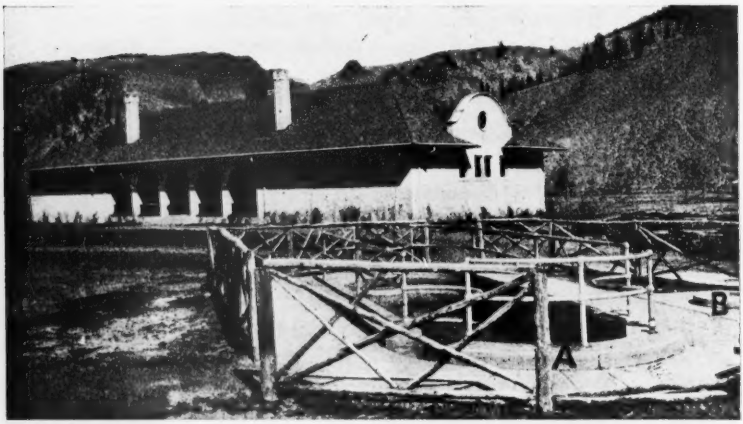

FIG. 14. The bath house and a hot spring of Wagon Wheel Gap. *A* is a hot spring; *B* a cold spring.

travertine which are continuous with the lake beds at Creede, Colo.[2] These tuffs overlie, very irregularly, latites and rhyolites. The latites form the upper slopes and extend several thousand feet above the Rio Grande. Just north of the mouth of Goose Creek, near the Rio Grande, a small exposure of rhyolite, the

[1] Emmons, W. H., and Larsen, E. S., "A Preliminary Report on the Geology and Ore Reposits of Creede, Colo.," in Bull. 530, 1913, pp. 42–65.

[2] *Op. cit.*, p. 9.

upper member of the lower rhyolite at Creede, outcrops below the tuffs. Overlying the tuffs and separated from them by another surface of great irregularity is a thick flow of hornblende latite, probably corresponding to the latite of the McKenzie Mountain at Creede.[1]

The outcrop of the barite-fluorite vein here described is in the rhyolitic material of the lake beds. So far as observed, both of the walls are rhyolitic tuffs and breccias with, perhaps, some rhyolite flows. Just north of the vein, however, the rocks of the lower division, which are mainly latite but contain some andesite, are exposed. The contact between the two cuts sharply across the contours and runs nearly parallel to the vein. So far as known this is a normal contact. The hornblende latite which overlies the lake beds was not seen on the east side of Goose Creek, but it probably caps the ridge farther east.

The Hot Springs.—The three hot springs form a triangle, the sides of which are 40 to 50 rods long. All of them issue from the narrow flat which is only a few feet higher than the present level of Goose Creek. Spring 3 is on this stream, spring 1 is nearly 200 feet from it, and spring 2 is about 600 feet from Goose Creek. The positions of these springs are shown on Fig. 15. The waters of springs 1 and 2 are carried to the bath houses, but spring 3 is allowed to flow directly into Goose Creek. In the stream of hot water from spring 3 green, yellow and brown algæ are growing.

As stated in a pamphlet issued by the company that owns the resort, the temperatures of these springs, 1, 2 and 3, are respectively 135° F., 150° F., and 140° F. Number 2, which is the hottest, is termed the "boiling spring," but its temperature is below the boiling point of water. Bubbles of gas issue continually from all of the springs, and these give the impression of boiling water. This gas is probably a mixture which contains some sulphur compound, and probably nitrogen. After standing, the waters of the springs and baths are covered with a thin yellowish-brown scum which is rough to the touch, and is probably native sulphur. A faint odor, probably from a sulphur com-

[1] *Op. cit.*, p. 9.

pound, was noted from the gas which issues from spring 1. From the smell it was thought that this gas contains a faint trace of hydrogen sulphide, but this was not confirmed. Flame was applied to the bubbles of the three springs, but none of them ex-

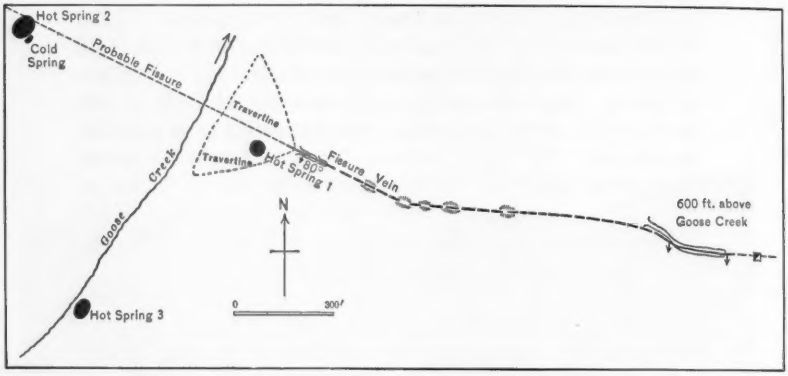

FIG. 15. Sketch showing position of hot springs and associated mineral deposits of Wagon Wheel Gap, Colorado.

ploded, and the odor may be due to other sulphur compounds.[1] Since a candle will burn at the bottoms of the cement basins into which the springs issue, CO_2 is probably not abundant in the gas. Being heavier than air, CO_2 would accumulate in the basins. Nitrogen, however, being lighter than air, would probably not accumulate. Although no analyses are now available, it seems most likely that this gas is mainly nitrogen.

Analyses of the waters of each of the three springs are stated on page 239. These were made at Colorado College in 1904. The analyst is not named in the pamphlet issued by the company that owns the resort. The waters of all the springs are "alkaline-saline, sodic-calcic-magnesic, sulphated-muriated-lithiated." It is not stated whether boron, fluorine, barium, and phosphorus were looked for.

[1] Hydrogen sulphide is mentioned in an analysis by O. Loew in U. S. Geographical Survey west of 100th meridian. Geo. M. Wheeler in charge. Vol. III., p. 623, 1875.

ANALYSES OF WATERS OF THE HOT SPRINGS OF WAGON WHEEL GAP, COLORADO.

	Parts per Million.		
	(1)	(2)	(3)
SiO_2	Not det.	84	73
Fe	3	2	1
Al	2	1	Trace
Ca	46	66	17
Mg	53	15	15
Na	347	393	360
K	52	133	156
Li	8	11	9
CO_3[1]	582	353	431
SO_4	161	457	135
Cl	66	195	210
Total	1,320	1,710	1,407
Temperature	135° F	150° F	140° F
"Carbonic acid and water in bicarbonates"[2]	1,062	788	1,055

Recalculated by G. L. Harrington to parts per million from analyses made for the company at Colorado College in 1904.

The hot waters contain high and almost equal amounts of mineral matter. Carbonates are abundant in all. In 2, the sulphates are more abundant than chlorides, but in 3 chlorine is more abundant than SO_4. Sodium is the most abundant base, although considerable potassium is present in each of the three waters. The alkaline earths, iron, and magnesia are present in appreciable quantities, although these are considerably less abundant than sodium. Lithium is present in all of the analyses. Silica is not stated in analysis of No. 1. If it is assumed to be 78.3 parts per million, the average of 2 and 3, the total mineral matter of No. 1 is 1398. parts per million, or nearly that of 2 and 3.

Although the amount of the total material dissolved is nearly the same, the solutions show considerable differences in composition. Since, however, these springs are close together, and since they are the only hot springs known in the vicinity, it is reasonable to suppose that they have a common origin. If at

[1] CO_3 is included under "Carbonic acid and water in bicarbonates" in the report. It is here computed to satisfy the bases for normal carbonates after SO_4 and Cl have been satisfied.

[2] Quoted from the report.

their source they have the same composition, it is certain that their composition has been changed by processes other than by dilution with pure water. It is readily apparent that sodium, lithium, and carbon dioxide are most nearly constant. The other elements vary greatly in the three analyses. Except Cl and SO_3, all of these elements are doubtless present in considerable amount in the rhyolitic tuff, through which the springs issue, and pyrite, which is present in appreciable amount along the fissures, might supply the sulphur for SO_4. On the other hand, it seems improbable that chlorine or lithium could be supplied by the rhyolite.

If these three waters have a common source, and have approximately similar compositions at that source, their composition might be modified by reactions with the wall rocks of the fissures and doubtless those which move most slowly or through the longest paths, or those which come in contact with the greatest surfaces before arriving at the points of issue, would be most affected. The wide variations in the amounts of the common rock-making elements that the waters contain suggest that they have reacted with the wall rocks in different degrees, and this seems to point to a deep source or to conduits of varying length and character.

It is not reasonable to suppose that these waters are of the vadose circulation. The vadose circulation is probably represented by a cold spring (*B*, on Fig. 14) that issues a few feet from spring 2 (*A*, on Fig. 14), so close that both are walled up in the same small concrete structure. No analysis of the cold spring is available, but its composition and properties are said to differ greatly from those of the neighboring hot spring. It is doubtless a water of shallow origin.

THE MINERAL DEPOSITS.

Interest is added to the hot springs because of their closely associated mineral deposits. Fig 15 is a sketch of the region near the springs, and the slope of the high ridge that lies east of them. The distances were measured by pacing on a steep slope and are not accurate, but the relative positions of mine workings, outcrops of veins, and other features are approximately as shown.

A deposit of travertine indicated on Fig. 15 surrounds spring 1, and extends to the channel of Goose Creek. The ridge to the east of the springs is strewn with many tons of large barite crystals and with float of fluorite, jaspery silica, and sugary calcite. Much of the fluorite is massive or fibrous. Some specimens show limonite and a white material, probably kaolinite, is covered with manganese flowers. Barite shows stout crystals, and the following forms, according to Mr. Oliver Bowles, are developed: Basal pinacoid (001), brachydome (013), brachypinacoid (010), bipyramids (113). Of these the latter is a rather uncommon form. Of some specimens the paragenesis is (1) barite, (2) fluorite and calcite. Some siliceous rock from a point near the vein and high on the hill is composed of minute stemlike siliceous particles, intergrown with opal, calcite, and fluorite. Assays of this, made with unusual precautions against error by Mr. Edmund Newton at the School of Mines, University of Minnesota, show .007 oz. gold, and .283 oz. silver per ton. A piece of fluorite float (Fig. 16) is sprinkled liberally on the surface with little rhombic

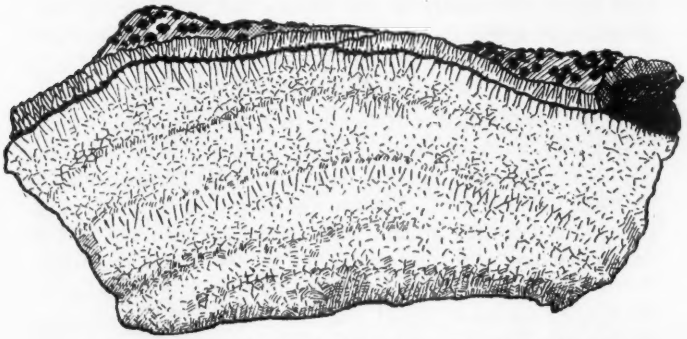

FIG. 16. Fluorite and oxidized pyrite, from Wagon Wheel Gap.

dodecahedrons of pyrite oxidized to limonite, and a layer of limonite is interbanded with fluorite.

East of spring 1 about 100 feet, a tunnel is driven 75 feet along a lode that strikes S. 70° E. and dips about 80° S., occupy-

ing a zone of sheeted rhyolite three feet or more wide. This zone includes veinlets of barite and fluorite an inch or more wide. Abundant pyrite is found in the highly altered wall rock. A prominent fracture of the sheeted zone dips 80° S., and is marked by grooves that make 5° with the line of steepest dip, plunging steeply east. Above this tunnel numerous pits and open cuts expose the vein which may be followed for over 1,000 feet. It strikes about S. 65° E. for about 320 feet, then, to judge from somewhat scattered outcrops, it turns and strikes nearly east. Owing to the numerous outcrops and short tunnels, there is little doubt that the vein is a single fissured zone.

About 1,250 feet southeast of spring 1, and 550 feet (aneroid) above it, a tunnel is driven south of east about 200 feet. The tunnel encounters a fissure about 40 feet from the portal. The footwall is rhyolite tuff, and the hanging wall is also of rhyolite, but contains few large fragments. The rocks on both sides of the vein are greatly altered. Indeed, for several hundred feet on either side no fresh rock was found. At the vein the wall rock shows the texture of the rhyolite tuff, but is completely altered to an aggregate of quartz with some chloritic mineral and sulphides. The fissure is well defined, slickensided, and dips about 67° S. W. Along this fissure, in oxidized gouge-like material, are tabular masses of fluorite from one to six inches thick. It is sugary, white or faintly purplish pink, and some specimens are fibrous, the fibers being at one place nearly perpendicular to the plane of the fissure. Fluorite also forms crusts, and crystals (100) are deposited around vugs. One specimen shows well defined banding of fluorite of varying shades of pink and white. Pyrite is abundantly developed in the rhyolite along the fissure at the base of the lower tunnel, and as already stated, some small crystals of oxidized pyrite were noted on the surfaces of fluorite float. A little crushing has evidently taken place since some of the minerals were deposited. Near the east end of the tunnel the fluorite is about two feet thick and appears almost pure. A brownish yellow material, thought to contain jarosite, gave a negative test for sulphate. Mr. Tug Wilson, who owns the pros-

pects, states that he obtained assays of $7, mainly gold and silver, from the ore. Messrs. Corson and Gish, assayers at Creede, also state that they obtained $2 to $3 to the ton in several assays of the ore. Mr. Wilson states that fluorite is barren, the precious metals being in the altered rhyolite near the fissures. Fluorite taken from the upper vein by the writers was assayed with special precautions by Mr. Edmund Newton at the School of Mines, the University of Minnesota, and showed .03 oz. gold, and 4.55 oz. silver to the ton.

While the ore that has been developed probably could not be worked for the metals at a profit, owing to the small size of the deposit as now developed, it is noteworthy that mines with larger reserves exploit ore bodies that are not of higher grade than this is reported to carry. If the iron smelters at Pueblo should offer a good market for the fluorite for flux, it is not improbable that these deposits may at some time be worked in a small way for fluorite.

A connection between the hot springs and the fissure vein is obvious from inspection of the map. If the vein continues along its strike it passes within a few feet of spring 1 and through spring 2. The deposit of travertine, part of which is mapped from physiographic evidence, appears to be bisected by the vein (projected), and since the spring is now at a slightly lower level than the highest point of the travertine body, which seems to lie along the fissure, it is thought that the spring once issued from the fissure at a point just below the portal of the lower tunnel of the vein. It is said, moreover, that masses of galena, barite, and fluorite were found in the bottom of the spring when it was cleaned out preparatory to walling it up.

A careful partial analysis of the travertine was made in the laboratory of the United States Geological Survey, by Mr. George Steiger, with the following result:

Pb	None
ZnO	0.007
BaO	0.045
F	0.22
Cu	None

This corresponds to a content of 0.008 per cent. of sphalerite, 0.078 per cent. of barite, and 0.45 per cent. of fluorite.

DISCUSSION.

The high temperature of the springs (135° F. to 150° F.), and differences in composition from a neighboring cold spring suggest deep sources for the hot springs. The comparatively late age of the rocks, the close spacing of the three springs, and the absence of hot springs over a great area of similar rocks that are likewise fissured, suggest local conditions unlike those which obtain over much of the area. Possibly there is a connection below the surface with a mass of igneous rocks that has not yet cooled, but this of course is pure inference. Although the close spacing of the three springs suggests a common source, the difference in the chemical composition of the three springs suggests on the other hand either different sources or modification in different degrees of solutions from a common source.

The highest point on the vein is at least 700 feet above the springs. A little siliceous sinter with opal was found several hundred feet up on the hillside. Under the present physiographic conditions this deposit and this part of the vein could not be formed by the ascending waters, for obviously they would seek the lowest outlet as they do now. Without much doubt the springs have migrated downward with the erosion of the valley, and if so they have endured through the periods during which the country was sculptured into mountains. The physiographic relations of the springs and the deposits closely resemble those obtaining at Ojo Caliente, New Mexico.[1]

The majority of hot springs are in areas of volcanic activity; the greater number and most important deposits of the precious metals and of copper are closely associated with igneous rocks: these associations have suggested to many a connection between ascending hot waters and a certain important class of ore deposits. Many field relations point to such a connection. Along the Com-

[1] Lindgren, Waldemar, "The Hot Springs of Ojo Caliente," ECON. GEOL., Vol. 5, p. 22, 1910.

stock Lode,[1] which is well known for its production of the precious metals, hot waters issue in great abundance. It is reported that hot waters issue from a lode at Dunton, Colo., but we can find no data concerning this deposit in the literature. The mercury deposits of Steamboat Springs, Nevada,[2] and Sulphur Bank in California[3] are heated by ascending thermal waters to temperatures so high that mining operations on them were found to be impracticable below a very moderate depth. In the deposits now forming at Boulder Hot Springs, Montana,[4] which have a temperature of 164° F., Weed found small quantities of the precious metals (over $1 a ton). At Ojo Caliente, New Mexico,[5] Lindgren has shown a connection between the hot waters that now issue, the tufa that they deposit, and the metalliferous ores that occur along a fissure from which the springs probably rise to the surface.

On the other hand, it should be stated that no deposit of sinter or tufa in the United States, and none, so far as we know, in the world, is being successfully exploited for precious metals. If it is assumed that most of the ores of gold, silver, and copper have been deposited by thermal waters, a necessary corollary is that the rising waters deposit the greater portion of their load of these metals in the deeper zones that are exposed to man only after the sinters and more or less of the surface rock below them have been eroded. This conclusion seems to us inevitable. Even those who are not impressed with the theory that magmatic waters are the principal agents in the deposition of lode ores of copper, gold, and silver, allow that such ores are deposited in the main by ascending thermal waters. The distribution of deposits with respect to intruding masses, and the evidence afforded by alteration of the wall rock[6] point clearly to the agency of hot waters.

[1] Becker, G. F., "Geology of the Comstock Lode and Washoe District, Nevada," Mon. III., U. S. Geol. Survey, 1882.

[2] Becker, G. F., "Geology of the Quicksilver Deposits of the Pacific Slope," Mon. XIII., U. S. Geol. Survey, 1888, p. 331.

[3] Ibid. p. 259.

[4] Weed, W. H., XXI. Ann. Rept. U. S. Geol. Survey, part II., p. 233.

[5] Lindgren, Waldemar, ECON. GEOL., Vol. V., p. 22.

[6] Lindgren, Waldemar, "Metasomatic Processes in Fissure Veins in Genesis of Ore Deposits," *A. I. M. E.*, 1901, p. 498.

Much, from the standpoint of physical chemistry, may be said for the theory that the maximum deposition generally takes place at some distance below the surface, for chilling and mixing with partially oxidized vadose waters would surely tend to precipitate the metals, whether the latter were in alkali chloride, alkali carbonate, or alkali sulphide solutions.

Whether the region where the descending meteoric waters encounter the ascending thermal waters is 1,000 feet or half a mile deep, or deeper, cannot be stated. Doubtless it varies with the local conditions of the downward circulation. Probably surface agents are not important in the precipitation of some deposits, for many ore bodies, especially those of copper and of gold, were formed at depths that were doubtless considerably below the normal active meteoric circulation.

These relations appear to warrant the inference that precipitation may begin in the greater depths, before the ascending thermal waters encounter the active cold circulation, and that when the thermal waters mingle with the cold circulation the precious metals that have remained in solution are thrown down almost completely.

Unlike the precious metals, much iron may remain in the solutions and be deposited at the surface. Under some conditions it appears also that copper may be carried in solution to the surface. Several authorities have proposed or accepted the theory that the zeolitic copper deposits of the Lake Superior region have been formed at or very near the surface by solutions, probably hot, reacting on the lavas. We know of no workable copper or precious metals associated with acidic rocks that were formed at the very surface.

THE BARTH IRON ORE DEPOSIT.

J. CLAUDE JONES.

In the final report of the Fortieth Parallel Survey[1] a remarkable hill of iron ore was noted about six miles west of the town of Palisade, Nevada. The deposit has since been acquired and developed by the American Smelting and Refining Company and is known as the West Iron Mine. Since the present owners began operating this mine about six years ago, over 240,000 tons of ore have been shipped to their smelters near Salt Lake City.

W. H. Emmons[2] visited the mines in 1907 and suggested that the deposit might have originated as a result of contact metamorphism. He considered the rock that encloses the ore to be a fine-grained diorite, and stated that he found a metamorphosed rock, presumably of sedimentary origin, in contact with the diorite a short distance south of the mine.

Several days were spent by the writer at the mine during the fall of 1911 in a study of the deposit, and his grateful acknowledgment of the courtesy of superintendent H. G. Wilson and consulting engineer G. B. Wilson is here recorded.

The mine workings consist of an open pit about 200 feet in diameter and eighty feet deep, sunk in the solid ore. About twenty feet above the bottom of the pit a series of cross-cuts and drifts have been run as the upper or "dry" level in an extension of the ore to the south and east. Two levels approximately fifty feet apart vertically and below the upper level have been opened up down the dip of the ore body and connect with an inclined shaft that follows the dip of the ore for 180 feet. In the accompanying map of the mine workings (Fig. 17) the outline of the pit and

[1] King, Clarence, "Geol. Exp. of the 40th Par.," Vol. II, pp. 585–6.

[2] Emmons, W. H., "A Reconnaisance of Some Mining Camps in Elko, Lander, and Eureka Counties, Nev.," Bull. U. S. Geol. Sur., No. 408, pp. 112–113.

the workings of the upper level are shown in solid lines. The lower level is shown in dotted lines, while the intermediate is in dashed lines. The chief production of the mine has come from the pit and the development work in the levels, although at the time of the last visit the upper level was being caved.

The topography of the surrounding area is characteristic of the Great Basin in which it lies. The Cortez Range, trending north and south, rises two to three thousand feet from the broad flat

FIG. 17. Mine map of the West Iron Mine. Workings of upper level shown by solid lines, lower level by dotted lines, intermediate level by dash lines.

valleys on either side. It is a rough-hewn block of andesites and rhyolites that has been faulted up to its present position. The Humboldt River, flowing westerly, cuts directly across the range

in a narrow steep-walled canyon known as the Palisades (Fig. 18).

The canyon walls rise rather abruptly from the river for a few hundred feet, then merge with the gentler slopes that cul-

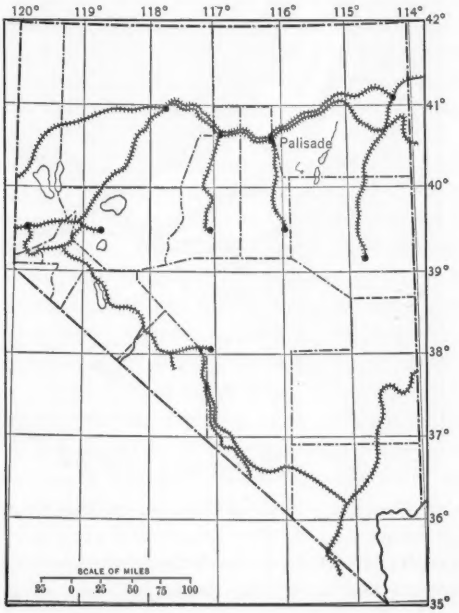

FIG. 18. Outline map showing location of Palisade, Nevada.

minate in the Carlin peaks to the north and an unnamed ridge to the south. Radiating from these elevations, several ravines and small canyons have deeply incised the slopes and finally lead to the river. One of these, Safford Canyon (Fig. 19), originating on the ridge to the south and deepening to the northwest, joins the river near the western end of the Palisade Canyon.

The west rim of Safford Canyon is a low ridge, the northern spur of which is formed by the outcrop of the ore body. Here

the canyon walls are somewhat gentler and the surrounding hills have the mature aspect of long-continued erosion. A short distance to the west of the mine stands Eagle Rock, an oval spine

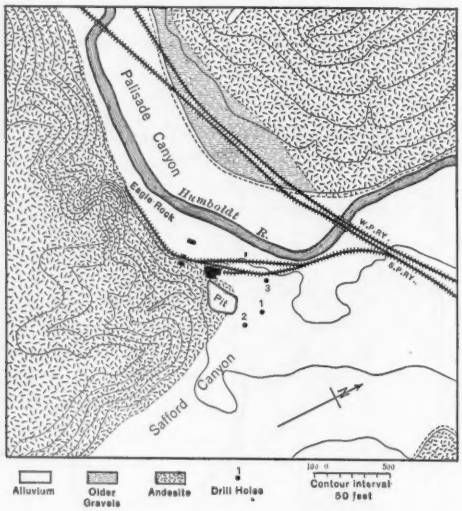

FIG. 19. Geological map of the vicinity of the West Iron Mine.

of rock deeply cleft at the top and rising precipitously from the water's edge, a landmark since the earliest days of trans-continental travel.

The slopes are thinly covered with coarse angular detritus that has resulted from the breaking up of the underlying rocks by the weather. As is common in arid regions, the mechanical disintegration is in advance of the chemical, and the soil is thin and scanty. Occasionally ledges and boulders of harder rock project from the débris in rather fantastic shapes and give a touch of variety to the otherwise barren surface of the hills.

In the vicinity of the mine the surface is formed from a thick andesitic flow. In the report of the Fortieth Parallel Survey

only the lower portion of the flow was called an andesite and the upper part was classified as a trachyte. At first sight this division of the rocks into two distinct parts seemed to be valid. The lower rock was darker and better crystallized than the more glassy rock that capped it, and there was a fairly definite line of contact between them. A close examination of the contact failed to show any evidence that the two parts were actually distinct flows, and as the microscope showed only such differences as usually occur in the different parts of a surface flow, the rocks may be considered as such.

The base of the flow is well exposed at the mine and near the railroad bridges across the river (see Fig. 19). In the latter location it stands 25 feet or more in a nearly vertical wall with a rude columnar structure. This phase is quite brittle and breaks easily into angular fragments. It is olive green in color, the surface broadly marked and subdivided by a network of dull red bands of iron oxide. Numerous greenish red phenocrysts, which were later proved to be altered olivine and hypersthene, speckled the darker ground mass of the rock.

Thin sections showed the rock to be porphyritic, the phenocrysts forming about 10 to 25 per cent. of the whole. The phenocrysts were euhedral olivine crystals, now completely altered to serpentine and hydrous iron oxide; fresh subhedral crystals of augite; lath-shaped crystals of plagioclase showing polysynthetic twinning and zonal structure and ranging in composition from andesine to andesine-labradorite; and occasional rectangular hypersthene crystals completely altered to fibrous serpentine. Rarely a rounded and embayed quartz-grain was found, and microscopic crystals of apatite occurred sparingly as inclusions in the feldspars. In contrast to the other phenocrysts, the feldspars graded in size down to the microscopic crystals in the ground mass.

The ground mass is formed almost entirely of small elongated crystals of a rather basic andesine. These are arranged in roughly parallel lines that suggest flowage and often bend around the larger phenocrysts. A smaller proportion of hypersthene

and occasional biotite crystals occur among the feldspars and are usually parallel to them. The remainder of the ground mass is made up of small flakes of hematite which sometimes have euhedral outlines suggesting them to be pseudomorphs after magnetite.

In places a more heterogeneous arrangement of the feldspars of the ground mass gives the rock a diabasic texture and again the individual crystals of the ground mass approach the magnitude of the phenocrysts and the rock has the appearance of a fine-grained norite. The latter phase is especially characteristic of the walls of the ore body. All of the rock is badly weathered, and even in the specimens obtained from drill cores two hundred feet below the surface, the texture is clouded and obscured by limonite, kaolin, and serpentine resulting from the partial decomposition.

The rock is an olivine-bearing hypersthene andesite. A representative specimen, collected near the railroad bridges, was analyzed by Mr. W. S. Palmer, of the Mackay School of Mines, the alkalies being determined by Mr. A. R. Merz, of the U. S. Bureau of Soils. The results were as follows:

ANALYSIS OF ANDESITE FROM BARTH, NEVADA.

SiO_2	53.00
Al_2O_3	14.32
Fe_2O_3	12.00
MgO	2.88
CaO	8.44
K_2O	2.48
Na_2O	2.94
H_2O-	1.45
H_2O+	1.01
S	trace
CO_2	1.14
P_2O_5	.17
Cl	trace
Total	99.83

The rock was as fresh as could be obtained, but was somewhat weathered, as is indicated by the rather high percentage of carbon dioxide. As the ferrous iron was not determined for lack of

apparatus, it is not possible to calculate the norm exactly but it contains 16.5 per cent. of orthoclase, 26.9 per cent. of albite, 20.0 per cent. of anorthite, approximately 9 per cent. of quartz, and the remainder in the ferromagnesian minerals, calcite. apatite, etc. The rock belongs to the dosalane class of the quantitative system and to the subrang Shoshonose. The predonderance of the feldspar noted under the microscope is confirmed by the analysis and the excess of silica explains the occasional phenocrysts of quartz found. The high percentage of iron is the most noteworthy, however; possibly it throws some light on the origin of the ore.

The upper portion of the flow, the trachyte of the Fortieth Parallel Survey, is composed of much lighter-colored rocks. When felsitic they are of a light lavender color and are dotted with large white phenocrysts of altered feldspar. A few darker specks of biotite and hypersthene are found on the surface. The more glassy varieties are darker and fresher. They contain the same phenocrysts in about the same proportion. Under the microscope the larger phenocrysts were found to be basic andesine with inclusions of glass, apatite, and iron oxide. Smaller phenocrysts of hypersthene and biotite were common and occasional rounded and embayed quartz-grains. Usually the phenocrysts showed perfect crystal outlines, but they were often rounded and partially resorbed. The larger hypersthenes were occasionally embayed and the cavities filled with crystallized ground mass. The ground mass was formed of a mass of microscopic crystals of feldspar and hypersthene in a matrix of glass which in the felsitic varieties was devitrified.

Except for the absence of olivine phenocrysts and the greater abundance of biotite in the upper beds, the relative proportions of the minerals are the same in both the upper and lower beds. The greatest difference lies in the texture and completeness of crystallization of the ground mass and this is the cause of the difference in the appearance of the rocks. In the absence of any evidence such as glass or baking or reddening of the lower beds at the contact, or other phenomena usually found at the contact of two flows, the two may be considered as one.

The only other formation, aside from the scant alluvium in the valleys, is a low terrace of bedded sands and gravels located at the northern edge of the river and well exposed in a cut of the Western Pacific Railroad (see Fig. 19). These probably belong to the terrace gravels deposited during the existence of Lake Lahontan.

The rocks in the vicinity of the mine have been gently tilted to the west as a part of the monocline forming the faulted block of the Cortez Range. Aside from a few minor faults of slight displacement and local extent noted in the ore body, there has apparently been no other displacement or diastrophic movement.

The ore deposit is located on the point of the spur marking the junction of Safford Canyon with the Palisade Canyon. A low silicified knob of andesite just west of the pit marks the original outcrop of the ore. At the surface the deposit is a thick lens about 100 feet in thickness and about 200 feet long, dipping 40° to the northeast. It is entirely surrounded by the andesite except where the gravels and sands of the stream beds rest upon its eroded surface to the north and east. The northern part of the foot wall as exposed in the pit is undulatory and lies in three benches as if step-faulted. To the south these are sharply truncated and the ore extends back to a nearly vertical wall of the andesite. While there has been some slight movement along the boundary of the ore body and slickensides are to be occasionally found, wherever there is a possibility of measuring the displacement, as in the case of the veins penetrating the foot-wall, the actual movement has been small. In no case was there sufficient movement detected to account for the step-faulting of the ore body as a whole and it is evident that the undulatory character of the foot-wall was produced at the time of the deposition of the ore.

The ore extends in anastomosing veins into the foot-wall, cementing the included fragments of the andesite into a breccia-like mass. While there is no gradation between the ore and the andesite, many of the included fragments of the latter show embayments and undulatory outlines, indicating their corrosion

and replacement by the ore-bearing solutions. Where the veins are especially thick and abundant, the fragments of andesite are changed in color to a deep green. A slide showed that the altered andesite was a mass of crystals of phlogopite lying in a fine-grained, indeterminate matrix deeply stained with iron oxide. Clusters of apatite radiated from the angles of the andesite fragments and phlogopite scales were especially abundant in their vicinity.

The hanging wall has been eroded except to the south of the pit where a fault of 10 to 15 feet has dropped it below the level of erosion. Here the ore has been caved for a considerable area and the hanging wall is well exposed. It is pitted and corroded, and although the ore does not penetrate it as in the foot-wall, it is decidedly undulatory on a much smaller scale. The three large undulations of the foot-wall are not repeated in the hanging wall although it is in a direct line with them.

In the lower levels of the mine the form of the ore body as developed shows a striking change from that in the pit. The large extension of the ore to the southwest is absent below and the ore pinches to a thin vein as the foot and hanging walls come together at the extreme south. From the latter point the ore rapidly widens until it is over a hundred feet thick at the north. This change of form is best brought out in the accompanying diagram (Fig. 20). The solid line represents the outline of the ore body at the upper level and pit. The dot and dash line is the form as developed on the intermediate level and the dotted line the form at the lower level. The levels are approximately 50 feet apart and the change in form from the irregular mass above to the elliptical lens below takes place in less than 100 feet in depth.

Three drill holes were put down to the east of the pit. Their location is shown on the map (Fig. 17). No. 2 is near the southern extremity of the ore body; No. 1 is in a direct line east of the inclined shaft; No. 3 is just south of the railroad spur that serves the mine. The following is the record of the strata passed through in drilling them.

LOGS OF DRILL HOLES AT BARTH, NEVADA.

South.	No. 1.	No. 2.	No. 3.	North.
Gravel.....	44′	42′	39′	
Andesite.....	90′	116′	8′	
Ore.....	60′	107′	157′	
Andesite.....	8′	9′	11′	
Total.....	202′	274′	215′	

It will be noted that the ore apparently thickens toward the north. There is a possibility that this may be due in part at least to a steeper dip of the ore body causing the drill to pass more obliquely through the ore at this point and so magnifying the width of the ore. Judging from the irregularity in the undu-

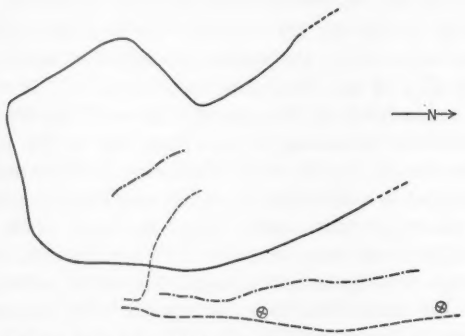

FIG. 20. Outlines of iron ore body. Outline on upper level and open pit shown by solid line, on lower level by dotted line, on intermediate level by dot and dash line.

latory boundaries of the ore body found in the mine, it is more likely that the increase in thickness is caused by the recession of the walls and that the ore body is actually larger toward the north.

The ore is massive and compact. Many fracture planes have been developed in it as a result of the diastrophic movements that formed the range. Some of these planes have been slickensided but the displacement has been very slight with the exception of the small step faults at the southern end of the upper level. The

irregular form of the ore body cannot therefore be explained by subsequent faulting and must have been produced either before or during the deposition of the ore.

The ore is massive hematite through which microscopic euhedral crystals of apatite are disseminated. It shows little variation throughout the ore body either in depth or towards the walls. It is somewhat magnetic and in parts of the mine will deflect a magnetic needle to a notable extent. Although no ferrous iron could be detected in any of the samples of ore analyzed, it is probable that some magnetite exists in the ore. All of the ore at present exposed has been subjected to the oxidizing effects of the circulating meteoric waters and judging from the present wetness of the mine it is certain that these have had free access to the ore. The magnetite that was originally deposited with the hematite has probably been largely oxidized, and it will be possible to obtain the correct composition of the original ore only when the mine workings have extended below the oxidized zone. A specimen obtained at the hanging wall contact on the lower level, showing the replacement of the andesite by the ore, contained much magnetite and it is probable that much of the original ore was magnetic.

The following analyses made by Mr. Palmer show the slight variation of the ore on the different levels.

ANALYSES OF IRON ORE AT BARTH, NEVADA.

	Upper Level.	Intermediate.	Lower Level
Insoluble	1.98	1.80	.45
Fe_2O_3	95.15	89.19	98.44
FeO	none	none	none
Al_2O_3	1.85	3.52	1.16
CaO	.43	1.94	trace
P_2O_5	not det.	.69	not det.
Ignition	.44	2.53	.05
Total	99.85	99.67	100.10
Total Iron	66.54	62.37	68.84

The ore is of high quality and uniformity and were it not for the lack of cheap fuel and high cost of transportation, it would be used for the manufacture of iron and steel. The phosphorus content is above the Bessemer limit, yet it is much below that of

the Alabama ores. Possibly with the development of electric smelting, this as well as other deposits in the state can be utilized for the making of iron and steel.

Under the microscope the ore was found to be quite porous and many minute cavities were distributed throughout the slides. A determination made by boiling a 20-gram fragment of the ore in distilled water for an hour showed the pore space to be 11.3 per cent. The ore was remarkably fine and even grained, and aside from the apatite crystals contained only the hematite. The apatites were elongate and rectangular in shape and averaged a half millimeter in length. They were clear and for the most part had perfect outlines. The larger crystals frequently had many inclusions of hematite grains. These were usually arranged parallel to the longer axis of the crystals. Occasionally the crystals were embayed and with ragged outlines as though the hematite surrounding them had begun to crystallize before the crystals had ceased their growth. For the most part, however, the apatite had already formed before the matrix of hematite had begun to separate from the solutions.

There is no apparent variation in the ore towards the hanging wall. Near the foot-wall, however, the apatite has a tendency to segregate in small nodules and veins. In these segregations the individual crystals increase in size, occasionally reaching a length of four to five millimeters. They are greenish red in color. The crystals have no definite arrangement except a slight tendency to radiate structure. They are in a matrix of hematite that merges with the ore on all sides. A few minute grains of quartz occur in the ground mass and one of the larger apatites completely surrounds a large grain of quartz.

At the foot-wall there has been a freer circulation of the surface waters and the ore has been hardened and cemented for a width of five or more feet. This phase is known as the "steel" rock on account of the difficulty with which it is drilled.
Assuming that the ignition is chiefly water, the analysis indicates that the "steel" rock contains nearly 20 per cent. of limonite. The streak of the "steel" rock is a yellowish brown in contrast

to the purplish streak of the ore from the main body, and from the slight change in the other constituents it is evident that the hardening is due to cementation by infiltrated hydrous iron oxide. The completeness of the cementation is shown by the slight amount of pore space (.01 per cent.) remaining in the "steel" rock.

The following analysis from the upper level shows the cause of this hardening of the ore.

	"Steel" Rock	Ore.
Insoluble	1.20	1.98
Fe_2O_3	92.59	95.15
FeO	none	none
Al_2O_3	.57	1.85
CaO	.57	1.43
P_2O_5	1.07	not det.
Ignition	3.71	.44
Total	99.46	99.85

Narrow seams and vuggs of calcite are fairly common in the upper level and layers of calcite crystals frequently line the walls of the few cracks and cavities. Occasional gouge seams of a light yellow clayey material are found near the foot-wall on this level. This material was found to be chiefly minute scales of phlogopite. Associated with the phlogopite were a few crystals of apatite and quartz. The color is due to iron oxide that stains the mica flakes which form the matrix.

Origin of the Ore.

It is evident from the large, irregular form of the ore body that it is either a magmatic segregation in the andesite or is a replacement deposit. There are many features that would suggest the former origin, but such a hypothesis is rendered untenable by the lack of gradation between the ore and the andesite, the absence of the rock-forming minerals even along the borders of the ore, and the penetration of the ore along fissures in the foot-wall, indicating that the ore was deposited after the solidification of the andesite.

On the other hand, the positive evidence of the replacement of

the andesite in the incomplete effacement of the andesite at points along the boundaries and the characteristic pitted and corroded walls clearly indicate that the ore has replaced the andesite and the deposit is a true replacement deposit.

The replacement of the andesite has been remarkably complete. It is only in favorable situations that any evidence of the stages in the process can be detected. Specimens were obtained from the

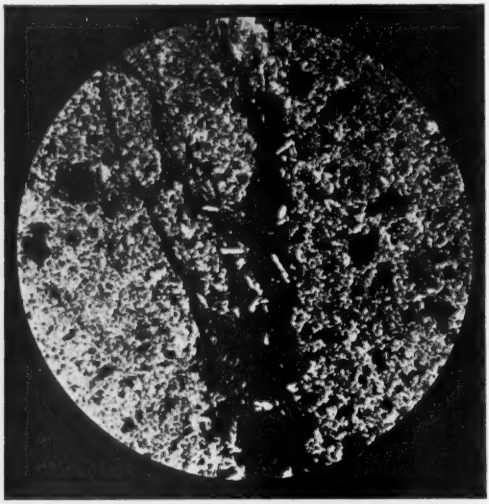

FIG. 21. Microphotograph of andesite showing manner in which solutions penetrated the rock along minute crevices.

foot wall that disclosed the manner in which the ore was deposited. The ore-bearing solutions penetrated the andesite along minute crevices, as is well shown in the accompanying microphotograph (Fig. 21). The walls of the fissure were attacked and the fissure broadened, as is indicated by the blunt termination of the veinlet of ore. The transparent acicular crystals in the dark-colored ore are minute apatites similar to those found in the mass of the ore. As the solution migrated from the fissure into

the bordering andesite, a narrow zone was developed along the fissure in which only the feldspars remained of all the minerals of the andesite. The feldspars were quite fresh and the last of the minerals to be replaced. In the process a fine indeterminate matrix was developed at the contact of the ore with the andesite and in one specimen only was the suggestion of the phlogopite scales to be recognized. Phlogopite is apparently one of the intermediate products of replacement and is only found at the borders of the ore. Calcite is particularly abundant in the incompletely replaced andesite and seems to be developed as the ore is deposited. From the high content of lime in the andesite this is not surprising, though the source of the carbon dioxide is not so certain.

The striking feature is the extremely narrow zone of partial replacement. At the hanging wall this zone is especially narrow and rarely is evident even in a microscopic examination. Professor Irving in his recent paper on "Replacement Ore Bodies"[1] has called attention to the fact that igneous rocks are rarely completely replaced. In the present instance, however, this has taken place with remarkable completeness and no trace of the former minerals or texture of the andesite can be found in the mass of the ore.

The Barth deposit belongs then to Irving's second class of replacement deposits, those that have sharp and abrupt boundaries between the ore and the enclosing rock. Of the criteria which he cites for the recognition of such deposits, the Barth deposit has the following:

1. The euhedral crystals of apatite developed in the andesite at the borders of the ore body.
2. The undulatory and corroded walls.
3. Complete absence of banded structure of crustification.
4. Blocks of unreplaced andesite completely surrounded by ore near the foot wall.
5. The extreme irregularity of form of the ore body.
6. Decrease in volume of the ore over that of the rock as shown by the increased pore space in the ore.

[1] ECON. GEOL., Vol. 6, pp. 527–561, 619–669.

7. The large excess of the volume of the ore over the original pore space (5 per cent.) of the andesite.

The origin of the ore-bearing solutions is not so clear. The original minerals associated with the ore are hematite, magnetite, fluor-apatite, and phlogopite. Primary magnetite and hematite are characteristic of ore deposited under conditions of considerable heat and pressure.[1] Phlogopite is considered as characteristic of igneous and metamorphic rocks.[2] Apatite is found under all conditions, according to Emmons. Usually, however, apatite is considered as being most characteristic of igneous and metamorphic rocks. Synthetic production of apatite has been possible only under conditions of considerable heat and pressure. Cameron and McCaughey[3] indicate that apatite is not formed at temperatures usually found at the earth's surface. Cameron[4] states however that chlor-apatite has been obtained by heating a solution of di-calcium phosphate and calcium chloride to a temperature of 200° Centigrade in a closed tube. Though apatite has been found in sedimentary rocks, its origin is not definitely known.

Occurrences of apatite that have apparently been deposited from surface solutions have been described. Bischof[5] notes an occurrence of apatite crystals in small drusy cavities in phosphorite. Eakle[6] recently noted in the ores of Tonopah, Nevada, minute crystals of apatite of undoubted secondary origin. Yet it is a striking fact that neither fluorine nor chlorine could be detected in either of these occurrences.

Rogers[7] in examining a similar mineral from Tonopah found that the haloids had been replaced by the carbonate radical and that the supposed apatite was in reality dahlite.

The apatite contained in the ore at Barth is of the fluor variety

[1] Emmons, W. H., "A Genetic Classification of Minerals," Econ. Geol., Vol. 3, pp. 611–627.
[2] Iddings, J. P., "Rock Minerals," 1906, p. 434.
[3] "Apatite and Spodiosite," *Jour. Phys. Chem.*, Vol. 15, pp. 463–470.
[4] Personal communication.
[5] *Chem. and Phys. Geol.*, Vol. 2, p. 23, 1855.
[6] Univ. Cal. Pub. Dept. Geol., Vol. 7, p. 16.
[7] *Am. Jour. Sci.*, 4th Ser., Vol. 33, pp. 475–482.

and as far as known this has never been found or produced under conditions such as rule at the surface. Consequently it is believed that the apatite at Barth could not be formed from the cold oxidizing waters of the surface.

On the other hand, there is a conspicuous lack of any of the silicate minerals that are characteristically produced under condition of great heat and pressure such as distinguish deep-seated and contact deposits. The alteration of the andesite is very slight even at the ore contact. There are no garnets, pyroxenes, or epidote, that are abundant where rocks have been intruded by deep-seated igneous rocks.

There is a lack of the bleaching and leaching of the andesite such as is common around hydrothermal deposits, yet there is a small amount of bleaching and silicification at the outcrop as if there had been some action of this character. The minerals forming the ore body indicate that they were deposited under conditions of some heat and pressure, and from the lack of extensive metamorphism of the andesite we are forced to conclude that the ore-bearing solutions were not very hot. They may have been about 200° to 300° Centigrade. These solutions must have been associated with some igneous rock to acquire the necessary heat. The rocks that form the Cortez Range are the latest igneous rocks in the vicinity and the andesite is a part of the series. Perhaps the best that can be said at present is that the solutions came either as an after effect of the flow of andesite or as a basic splitting of the magma that gave origin to the following rhyolites that cap the andesite.

Of the occurrences of iron ore deposits which have been described, that at Iron Springs, Utah,[1] most nearly resembles Barth. There an ore of a similar mineralogical composition occurs along the contact of andesite and metamorphosed limestone as well as in veins in the andesite. The ore was deposited after the metamorphism of the limestone and its origin is believed by Leith and Harder to be due primarily to igneous after effects of the intrusion of the andesite.

[1] Leith and Harder, "Iron Ores of Iron Springs Dist., Utah," U. S. G. S. Bull. 338, 1908.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, Sheffield Scientific School of Yale University, New Haven, Conn. The full name of the author should be attached to all communications.

FIELD AND OFFICE METHODS IN THE PREPARATION OF GEOLOGICAL REPORTS.

Sir: I have read with interest many of the contributions to the current discussion of field methods. Originality cannot be claimed for most of these details of field or office procedure, but the personal experience of the individual worker has value whether he is discussing a method all his own or one to be credited to some other geologist. I have in mind two minor suggestions as to notebook methods that I early found helpful, and one detail in geologic map-making that I am convinced is essential to success.

Realizing the advantage of putting down in black and white every impression and suggestion gained in the field on the interpretation of physiography, general structure, stratigraphy, sequence of events, origin of rock structures, etc., and also appreciating the danger of statements of hypotheses indiscriminately mixed with record of observed facts, I adopted the simple device of reserving a portion of the notebook for the storage of hypotheses. My experience was that as the season advanced old hypotheses died about as fast as new ones came into being, but the record of their short lives was set down and available for reference. They served their purpose of stimulating the hunt for facts, but were not recorded where they might be mixed with field observations and mistaken for facts.

Incidental to this mention of note-taking, I would add a word of personal confession. Geologic reports written in the office are sometimes justly criticized as too long and too exhaustive in treatment, but I have never possessed a notebook that shows evidence of too much thinking in the field or that contains too many facts recorded in the open.

Another simple device found to possess some advantage was the insertion in the notebook of small photographs of important outcrops having real illustrative value, such as short-range views of contacts, structural details, and rock textures. In the course of the office study of these notebooks, these illustrations side-by-side with the descriptions tended to restore the field attitude of mind.

More important, however, was a rule which I adopted in my own western work—namely, not to move camp until the combined field sheet was up-to-date and contained the cartographic data collected by every geologist working in the party. This practice sometimes necessitated postponement of moving day, but it resulted in leaving the field with a completed map—the field map usually showing more lithologic and stratigraphic units than the published map, but never less. Cartographic units can be easily combined in the office, but their subdivision away from the field is not so easy, if this also involves complete delineation of boundaries and consistent interpretation of structure. To return to a locality to pick up an overlooked detail in geologic mapping means not only waste of time, and possibly also months or years of delay in publication, but in some areas, far removed from transportation lines, the extra expense involved would be prohibitive. The chief geologist of the Survey estimates a saving of many thousands of dollars to the Survey had such a rule been put in force twenty years ago, and I would add as more important the incidental escape from considerable well-deserved criticism of delayed reports. The best place to make a map, geologic or topographic, is on the spot, and the best time is while you are there.

GEO. OTIS SMITH.

CONTROL FOR GEOLOGIC MAPPING IN THE ABSENCE OF A TOPOGRAPHIC BASE MAP.

Sir: An adequate topographic base map is without doubt the ideal means of control for geologic mapping, but such a map is very expensive to make, and in many cases is not available, so that the problem of gaining a control suitable for geologic work is an ever present one in many regions. Government surveys and large land holding corporations are continually demanding geologic examinations in topographically unsurveyed areas, and if the work is of an economic character considerable precision in the control used is necessary to obtain results of much value.

Without a topographic base and under necessity of doing mapping in considerable detail, the geologist's only resort is to the plane-table and to the field methods of the topographic engineer. An excellent exposition of these methods as adapted to geologic work was published by Carroll H. Wegemann in a recent number of this journal.[1] By using triangulation or stadia traverse, or a combination of the two, and by computing vertical angles for elevations, the field worker can make his own control as he proceeds and obtain admirable results, the only difficulty being that he has to spend a large or major portion of his time at purely engineering problems to the detriment of his geologic work. The exacting mechanical operations, together with the necessary vertical angle computations, are a distinct hindrance to his main purpose. What the geologist really needs for field work under these conditions, is a readymade control consisting of closely spaced, easily located points in the field, together with a plane-table sheet giving the location and elevation of these points. Given such a control he is almost as well equipped as with a good topographic map, and certainly better off than if equipped with a base map, the topography of which is crude or inaccurate.

While engaged in field work in eastern Montana during the summer of 1910, the writer found that an ordinary stadia traverse line could be readily retraced in the field, if each of its points were

[1] Carroll H. Wegemann, "Plane-table Methods as Applied to Geologic Mapping," ECON. GEOL., Vol. 7, pp. 622–637, 1912.

marked by a small surveyor's flag. By placing a copy of the original field sheet on a plane-table, and using an open sight alidade, the geologist could work over such a line and map and record the necessary geologic data, without being hindered by purely engineering operations. Other advantages of working in this manner soon became apparent, namely: (1) A chief source of error in stadia traverse was eliminated by being able to orient by back sights instead of being dependent on the vagaries of a compass needle. (2) The usefulness of the barometer was much increased because it could be reset at frequent intervals, and thus afford a continuous vertical control that could be relied upon within fairly narrow limits. (3) The area controlled by a single traverse could be greatly extended by working away from the line a mile or more and locating by intersections from the flagged points. By working in this manner traverse lines two to three miles apart could be depended upon to control the entire area between them.

The locations on a single straight traverse line are apt to be inaccurate, but if the line is looped and closed on itself, and any resultant closing error equally distributed to all points, the results are equally as satisfactory as those obtained by ordinary plane-table triangulation. This makes it possible to control an entire season's field work, by building up a system of closing and interlocking traverses such as is presented on page 269 (Fig. 22).

For the sake of completeness, the equipment used and the procedure followed will be rather fully described with the exception of flagging the points occupied, although on the whole the methods are those commonly used in the execution of an ordinary stadia traverse with the plane-table.

FIELD FORCE AND OUTFIT.

Two controlmen, an instrument man, and a rodman can provide control points sufficient to keep from one to three geologists continuously engaged. The proper balancing of a field force will depend upon the intricacy of the geology. The instrument man

need not be a trained geologist but should have a knowledge of elementary plane surveying. Any active intelligent person can be trained to the duties of a rodman.

The instruments used are identical with those described by Wegemann,[1] except that both a telescopic alidade and an opensight alidade must be provided. The list includes a telescopic alidade equipped for stadia measurements, stadia rod, opensight alidade, plane-table, barometer, hand compass, boxwood scale, protractor, and plane-table needles. The flags used should be about 12 in. by 24 in. in size and can be obtained mounted on light 36 in. sticks. A flag with a plain white field carrying a large red center, or vice versa, makes an excellent color combination. Parti-colored flags are not easily seen against a variegated background.

MAPPING SCALE.

A suitable scale will vary with the amount of detail desired in the mapping. While a scale smaller than two inches to one mile can often be used to advantage in plane-table triangulation, such a scale would be of doubtful value in running a plane-table traverse with stadia measurements where the length of shot used averages between 1,500 and 2,600 feet. Generally speaking the limit of error in plotting on the plane-table sheet, which varies with the scale used, should equal the limit of error in the corresponding stadia measurement, which, with a 2,000 ft. average shot, is just about balanced by plotting on a two inches to one mile scale. For very detailed work a scale of four inches to one mile, or even larger, should be used with a corresponding reduction in the length of the stadia measurements.

METHOD OF PROCEDURE.

Fig. 22 is a copy of a completed control sheet for about 36 square miles, as it would come into the hand of the geologist, prior to the geologic mapping. Camp or headquarters had been established as indicated, nothing being known of the region except the general position of the main drainage lines as shown by

[1] ECON. GEOL., Vol. 7, p. 622, 1911.

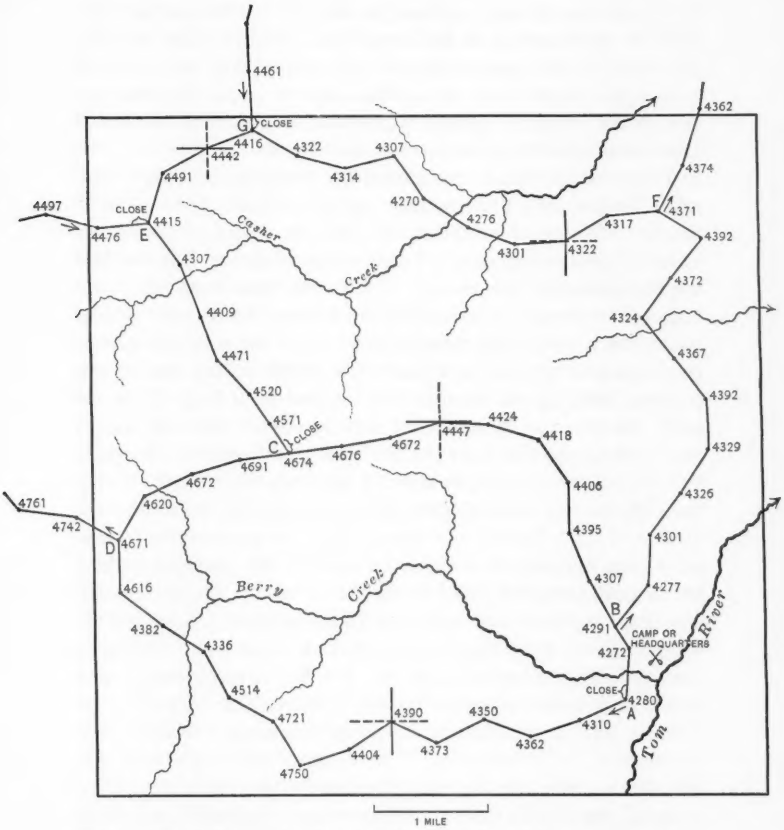

FIG. 22. Copy of a completed control sheet for about thirty-six square miles. Sheet is now ready for geologic mapping.

an ordinary geographic map, and the fact that the area was only slightly timbered and had a maturely dissected topography. The drainage known was sketched in pencil on the sheet to be used by the instrument man, and by following the interstream areas as indicated by this drainage the route of his first traverse, starting

at *A* and closing at *A*, outlined in advance. A line at an angle equal to the magnetic declination obtained from a chart showing the isogonic and agonic lines of the country was then laid off with a protractor from a meridian line, in order that the first orientation should be placed approximately on the meridian, all later orientation being obtained by backsights.

The point *A* was then occupied by the instrument man who made his first orientation by aligning his compass with the line of magnetic declination on the sheet. The elevation of point *A* was known from the results of a former railroad survey, but if it had not been known an assumed elevation could have been taken and adjusted to some known datum point later in the season. Meanwhile, the rodman had taken a position on the most prominent point about a quarter to a half mile ahead on the line of the traverse, held his rod on this location, and set a flag, which, on every traverse run, he numbered serially from 1 up, with waterproof crayon, so that later the geologist could readily refer each flag to its corresponding location on the plane-table sheet. After the distance had been plotted, the angle reading recorded, and the line of sight drawn from *A* to the first rod position, the instrument man signaled the rodman to move to the next point while he occupied the point just held by the rodman. The plane-table was again oriented, this time not with the compass, but by setting the alidade along the line of sight from *A* to the point now occupied, and sighting back to point *A*. The line of sight in each case was drawn four inches to six inches longer than necessary in order to have a considerable length of line against which to set the alidade for orientation. The distance and angle readings were again made and recorded, the move made, and a new point occupied, and in this manner the operations repeated step by step until the point *A* was again reached and the traverse brought to a close.

Adjusting Closing Errors on the Traverse.—The closing error on the completion of a six to eight mile traverse will vary from a few feet up to four hundred or five hundred feet and must be properly adjusted and distributed over the entire length of the line before the sheet is ready for the use of the geologist. This

is done by first drawing a line across the interval over which the traverse failed to close and extending it so that it is six feet to ten feet in length; then lines are drawn parallel to it through each point on the traverse by taking two 45° triangles and setting one on the line extending over the closing error and sliding the second against the first until each point on the traverse is reached; final closure is then made by shifting each point its proportionate distance along the line passing through it. The vertical angle computations, which can best be made on the completion of the traverse and not while in the field, will also show a closing error which will amount to two feet to ten feet for an average length of traverse. This is also adjusted by being apportioned to each point on the line. The instrument man is then ready to begin on the extension of his first traverse. Point *B* (Fig. 22) at a convenient location on this first traverse is chosen as a new starting point and a closure is made at any desirable point, as at *C*. Then *D* is taken as another initial point and closure made at *E*, a part of this traverse being run on an adjoining sheet. In this manner the control can be extended indefinitely over an area of any size, and covering any number of sheets.

Operations by the Geologist.—After any traverse error, that may be present, has been closed and the elevations adjusted, the geologist takes the original control sheet and transfers the points to the sheet on which he is to map the geology. This is easily done by laying one sheet over the other, and pricking through the control points on the first sheet to the second with a fine needle. The corrected elevations are also transferred to the geologic field sheet.

The geologist, mounting his sheet on a plane-table and using an open sight alidade, is then free to work over the traverse in whatever direction best suits his needs. He can make his set ups on the flagged points easily identified by their numbers or else locate by intersections from them. He can also reset his barometer at frequent intervals on these primary points and at no time need he be without an essential of prime importance for geologic mapping, namely, a precise and speedily obtained location in the field.

EUGENE STEBINGER.

FIELD METHODS OF GEOLOGIC MAPPING IN PUBLIC LAND STATES[1] OF THE WEST.

Sir: In order to avoid duplicating what has been stated in previous papers[2] on this subject, this article will not discuss plane-table methods at length, but will deal more with equipment and preparation for work.

Before beginning the actual examination of a treeless field wherein there are no maps but the Land Office plats, it is desirable to prepare field sheets. In most cases plane-table sheets 15 in. by 15 in. are best. On such a sheet the plat of a township can be constructed on a scale of 2 inches = 1 mile. The old method of constructing each sheet independently is not satisfactory, as it is found necessary to have each township plat join perfectly with its neighbor, and hence a balancing system may be successfully employed. Having secured Government Land Office plats of the township to be worked, the geologist begins with a township near the center of the area and constructs on one of the plane-table sheets a north-south line and an east-west one (two sides of the township). Now, from the dimensions given on the Land Office plat, he constructs the other two sides. This is done by locating the corners with a compass, by using radii equal to the lengths of the sides. Working outward from this township it will be necessary to extend only the two originally constructed lines which are to serve as base lines. In townships bounded by these lines two corners may be located by placing the field plat under the edge of the one already constructed and pricking through with a fine needle. Care should be taken to hold the sheets in a correct position while transferring. This is best done by thumb-tacks in the margins of the sheets. In the townships not bounded by the extensions of the two base lines three corners may be located direct from adjoining plats. Having located three corners of a township, the fourth is easily found by the compass as in the

[1] Published by permission of the Director, U. S. Geological Survey.

[2] Ransome, Frederick L., "The Plane-table in Detailed Geologic Mapping," ECON. GEOLOGY, Vol. 7, No. 2, pp. 113–119, 1912; Wegemann, Carroll H., "Plane-table Methods as Applied to Geologic Mapping," ECON. GEOLOGY, Vol. 7, No. 7, pp. 621–637, 1912.

construction of the first sheet. This process may be employed for as large a field as can be worked in one season. When correction lines are encountered the necessary offsets will have to be made, but this will not interfere with the scheme. Section lines should be drawn and the position and direction of streams indicated where they cross section lines.

If in the course of field work the Land Office data do not agree with the evidence on the ground, adjustments may be made as the field work progresses.

After the field plats are constructed, the next step is to determine the magnetic declination. This, of course, must be done in the field, but in ordinary examinations for land classification it will not be necessary to take a transit into the field. The meridian, therefore, must be determined without the use of a transit. A telescopic alidade may be substituted for the transit, provided great care is exercised in its use. A Johnson tripod should be employed, as it is firmer than the Bumstead tripod. Few alidades can be elevated sufficiently to reach Polaris, but a device may be improvised to enable the geologist to tilt the alidade at a higher angle. This may be accomplished to a fair degree of accuracy by attaching a compo-board about fifteen inches square to the top of the plane-table. One border of the compo-board should be a straight edge which should be placed in an east-west line and nailed so as to give sufficient play for elevating the other edge. The plane-table may be approximately oriented by a Gurley compass. (The Land Office plats give the magnetic declination for the year when the surveys were made.) Just before time for the observation (as given in any manual of surveying) place the alidade on the compo-board and by the combined play of the board and the vernier of alidade Polaris can be sighted; then proceed to find the elongation or culmination of Polaris, as the case may be, according to instructions in the manual. Having determined this, draw a line on the top of compo-board along the edge of the alidade, remove the prop from under the compo-board, and replace the alidade on the line, marking the extension of the line by setting stakes in the ground. The remainder of

the work may be done the next morning when the manual of instructions is again followed. The declination given on the Land Office plat may be accepted in many cases, but it is better to determine it anew as it will often be found to differ in different parts of the field.

In general it will be found that a five-man party can be conducted to better advantage than a larger one. The personnel of such a party would consist of a chief, two assistants, a teamster, and a cook. The chief of party should be a man of sufficient experience and practical ability to conduct the work properly and it will be to his advantage to know a few things besides geology. For instance, he should not only know how to do stadia work but he should know how to handle horses and how to build his own roads, if necessary. Both he and his first assistant should be willing to change places with the rodman and dig into the coal themselves with a shovel at frequent intervals, for the only way one can become familiar with coal is to work in it and study it. The first assistant should be a man of sufficient experience and training to handle the telescopic alidade and carry on stadia traverses and at the same time have sufficient geologic training to comprehend and map the geologic formations and coal beds. The second assistant should be employed primarily as a rodman, but should be a man of sufficient practical ability to take the plane-table and telescopic alidade and do stadia work when necessary. The teamster should know horses and how to get the best service out of them, but he should also be keen enough to be taught how to do stadia work and map coal outcrops. He not only, morning and evening, looks after the feeding of the horses, of which there should be about eight or nine, but he also goes along, primarily as rodman, with one of the plane-tables, as two men are necessary to each. The cook should be employed for cooking and looking after camp, but in emergencies it may be found necessary to use him even as a rodman.

It will be seen that two telescopic and one open-sight alidade will be needed in a five-man party. The type of telescopic alidade in use by the geologic branch of the U. S. Geological Survey is

known as the Gale alidade and is a light but very serviceable instrument.

Every man of the party that does any field work should be provided with a hand compass—the Gurley clinometer compass is preferred by the writer. This compass is adjustable for local declination, is provided with two level bubbles, and 4-inch sights, and is mounted on a 4-inch square base. Such a compass may be used in leveling and orienting the plane-table, in reading dips and strikes, or when desired may be used as an open sight alidade for preliminary or approximate locations. A small pocket tape for measuring coal beds will be needed and a hand level will also be found a time-saver for measuring thick beds. In this case one man holds the stadia rod at the base of a coal bed while the second man swings his hand level round from top of coal bed to rod and reads off the thickness, or, better yet, gets in a position so as to bring the rod between the eye and top of the coal bed. Field glasses[1] are needed, especially by the rodman, in reading signals, for it will sometimes happen that the man at the table will take shots 3,600 feet in length.

In holding the rod for a 3,600-foot shot the rodman places the rod on top of the saddle horse. The height from ground to top of saddle being known, the distance is readily calculated. Of course, readings of this sort are not used in places where the highest degree of accuracy is required. With alidade, plane-table, compass, level, notebook, celluloid protractor for plotting strike, pencils (a 9 H and a 4 H British graphite pencil), a small 6-inch, flat 1/31680 scale (graduated to 50-foot divisions), tape, small reading glass (a cheap pocket lens is adequate) for reading vernier of alidade, and, in most regions, a canteen for water, the geologist finds himself pretty well loaded down. In addition, the writer carries a camera and a geologic hammer, his own lunch, and feed of oats for the horse in starting out for the day's work. He has the rodman carry a short-handled shovel, which is attached to the saddle by two snaps. The notebook, compass, and level are carried in leather cases securely fastened about the waist by a

[1] A monocular glass is preferred by the writer, as it is more compact and just as effective as a binocular.

belt. The alidade is carried in a sling case over the shoulder; the tripod for plane-table either over the shoulder or in a leather boot (made for the purpose) attached to the saddle horn; the canteen, camera, hammer, lunch, and feed for horse are carried in canvas saddle bags, which swing across the horn of the saddle and over these the case containing plane-table board and field sheets are securely fastened by the saddle strings, the western stock saddle being used.

This discussion is meant especially to describe the methods employed in the examination of supposed coal lands and if there is doubt regarding the occurrence of coal in a certain township, a preliminary examination should be made. This can be accomplished by one man with a plane-table and alidade, either open sight or telescopic. If section corners can be found he can begin by placing section lines, recording the horse's pace by means of a tally register. The secret of finding sections corners by this means lies in the ability to make your horse keep a direct line and in the regularity of his pacing. At the section corners he can set up his plane-table and take a few shots at prominent buttes or other landmarks for triangulation stations. It will be found necessary in many instances to build cairns to be used as triangulation stations. After locating a few landmarks the examination may be continued entirely by triangulation after the manner explained by Mr. Wegemann.[1] The streams and outcrops of coal and the geologic boundaries should be sketched as the examination progresses, and time should be taken to prospect coal outcrops. This method is sufficiently accurate for a preliminary examination, and if little or no coal is found it will not be necessary to make a more detailed study of the township. If, however, coal is found, its outcrop should be traversed with the telescopic alidade and stadia rod. Whenever possible the stadia traverse should be tied to section corners. The outcrop of every coal bed of importance in the field should be traversed by stadia, and where the strike and dip are not distinctly evident the elevation should be determined also by means of vertical angles.

In townships where section corners can not be found, it may

[1] *Loc. cit.*

be necessary to measure a base and develop a system of triangles as explained by Wegemann,[1] or, in many cases, it will be possible to locate two or more triangulation stations from the adjoining previously worked township. By means of the needle holes at township corners it is an easy matter to join up field plats and transfer points on margins by puncturing with the needle. This will be a necessary process also in crossing township lines with a traverse on a coal outcrop. The needle employed may be either a No. 10 or No. 12. No. 12 is sufficiently large if the wax bead is extended well down toward the point. In making the bead on needles, ordinary sealing wax is employed and must be melted and molded about the head. Needles may be carried in band of hat or in the top of alidade case but the safest place is in the compass case, in the space provided for "Jacob's staff," where a cork is first fitted and needles stuck into it.

It will often be necessary to carry more than one field sheet for a single day's work. These extra sheets may be carried in the plane-table cover, but a compo-board of the same dimensions should be carried to protect the sheets against bending. In traversing a coal outcrop the bed is prospected at intervals, the frequency depending upon the irregularity of the bed. If the thickness and character of the bed is constant it will not be necessary to open prospects more than once in every mile along the outcrop, but if it is variable more openings should be made. At every place where the coal is opened a detailed section should be measured and recorded carefully in notebook. Each section should be given a number and this number should bear the initial of the man making the section and should mark the point on the map where the section was measured. It is a wise precaution, in order to prevent confusion, to number the stadia stations separately from coal sections, and to state in the description of the stadia station where coal sections were measured. As an additional precaution each coal section in the notebook should bear the legal subdivision down to the quarter section. In the writer's work, coal sections, fossil localities, points where photographs are taken, oil and gas wells, etc., are described as to township

[1] *Loc. cit.*

and range, section and quarter section, and in cases where a stadia level line is being run they bear two numbers—one the traverse station and the other the serial number. Both of these numbers occur on the map and in the notebook as well. The serial number is accompanied by a letter, the initial of the field man, whereas the stadia station numbers have no letter.

Dip and strike should be read at many places in the area, the number of readings depending upon the complexity of the structure. In a region of low dips the best practicable way to determine dip and strike accurately is by use of the stadia traverse, ascertaining the relative altitudes of three or more points on the outcrop which are not in a straight line, and working out the dip graphically.[1] For example, suppose one wishes to determine the dip and strike of a coal outcrop shown in the following sketch, *ABC*, Fig. 23. By stadia levels the geologist finds that *A* is 290

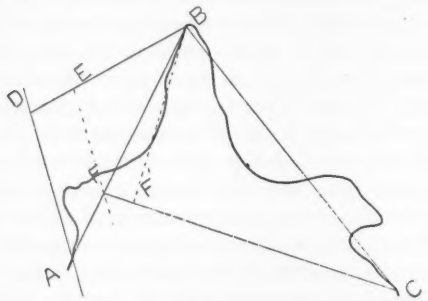

FIG. 23.

feet higher and *C* is 210 feet higher than *B*. To determine the strike of the coal bed it is necessary to find two points in the plane of the outcrop which are on the same level. Let *C* be one of these points and proceed to find the other. For convenience, strike off one digit in the figures and deal with 29 and 21 respectively instead of 290 and 210. Construct line *BD* equal to 29

[1] Prof. G. D. Harris published in "Geologic Mensuration," at Ithaca, New York, in 1904, a solution which is essentially the same as the one here presented.

divisions of the graduated scale, making *DBA* an acute angle, and construct *BE* equal to 21 of these units. Divide *BA* proportional to *BE* and *BD* by drawing *DA*, and constructing through *E* a line parallel to *DA* until it intersects *BA*. The point of intersection, *F*, is the point desired and is on the same level with *C*.

Proof: By construction $BA:BF::BD:BE$, but the altitude rises 29 (290) feet from *B* to *A*, so we can let $BA=29$ and let $BF=X$; therefore, 29 $(BA):X(BF)::29\ (BD):21\ (BE)$ and $X=21$. Hence, the altitude rises 21 (210) feet from *B* to *F*; so point *F* is 210 feet above *B* and must therefore be on the same level with *C*. The strike of the coal bed *ABC* then is the line *CF*, and since *B* is 210 feet lower than the line *CF*, it follows that the coal bed dips 210 feet in the horizontal distance from point *B* to line *CF*. The distance from *CF* to *B* is found by measurement to be 4,900 feet. Therefore the coal bed dips in the direction from *F'* to *B* (*F'B* being constructed perpendicular to *FC*) 210 feet in a horizontal distance of 4,900 feet, or 266 feet per mile which is about 2½ degrees.

V. H. BARNETT.

ILLUSTRATIONS.

Preliminary Preparation.

Sir: A detailed discussion of methods pursued in the preparation of illustrations to accompany reports on geology would necessarily include the question, "What constitutes a good illustration?" This is an open question and subject to debate; but preliminary preparation—the means by which an author brings together and prepares his illustrations in what might be termed manuscript form—is more vital because it is the origin of the finished product. Very little can be stated, in a brief article, on the details of final preparation and, indeed, so few geologists prepare their own final drawings that particular attention will be given here to a general discussion of original illustrations and preliminary preparation.

Compared with other fields of research, geology probably includes a larger variety of subjects or problems which need illus-

trating than any other, and it is also probably true that the expression of more than a fair average of detail and inherent character in its illustrations is called for. There are certain fixed rules and short cuts in the preparation of finished illustrations, as in all mechanical operations, which establish uniformity and save labor. Having been tried out they represent the best methods so far adopted and are generally well known to geologic draftsmen. But in preparing preliminary drawings, or what is termed *original material,* for illustrations, apparently no fixed rules or customs have been adopted and there is room for great improvement. It must be remembered that this original material not only furnishes the data but, to a great extent, controls the expression of those data in the finished illustration, the mechanical details being left to the illustrators—the draftsman first and the engraver next. With the high development of photography and the satisfactory results now obtained by the various processes of engraving, a geologist should be able to procure illustrations both expressive and pleasing. This cannot be accomplished, however, without the author's coöperation and full appreciation of the fact that good originals and clearly defined data must be submitted.

The purpose of illustrations is too well known to geologists to need comment further than a mere reference to their tendency toward curtailment of statements. This curtailment is well shown by frequent references to illustrations for details and represents a saving of text comparable with the saving of time effected by a field geologist when he makes a sketch of complex relations for record. The sketch tells its own story, just as the key map locates the area reported and the general section shows geologic relations.

In preparing illustrations two principal steps well known to geologists are involved. One is the preparation and assembling of the original material; the other is the preparation of the finished illustrations. The illustrations needed by geologists usually consist of maps, sections, plans, diagrams, sketches, and photographs. The wide dissimilarity existing in each of these groups

of illustrations makes any attempt to suggest standard methods of preparation impossible. A base map, for instance, may show great detail or it may be greatly generalized. It may show relief by contours, hachures, or hill shading, and it may show drainage in blue or in black; so that only an exhaustive treatise on map making could possibly cover each kind of base and the many kinds of information which base maps are made to convey. Let it suffice, therefore, to say that when a geologist needs a base map he must either find one already available for his purpose or compile one.

Before preparing an original illustration it is of great advantage for an author to ascertain the exact size of the text form and trimmed page of the publication in which his drawings will be used and, having learned these dimensions, to lay out each drawing so that it will have to be reduced to fit the volume. If the text measures four inches in width and seven inches in height, and the illustration is to be a text figure, his drawing should be six or eight inches in width and of a height which, when reduced one third or one half, will come within the seven inches. If his drawing is to be reproduced as an inserted illustration it should be of a size that when reduced by some simple fraction as one third off, one half off, three fifths off, it will fit a page or a folding page and leave at least an inch of margin of paper. A very narrow margin is a mark of poor bookmaking and should be avoided.

There are several reasons why a drawing should be prepared larger than publication size. If a drawing is to be engraved, reduction will bring the lines closer together and refine and improve the general effect of the printed cut. If a new drawing is to be made from it the draftsman will have the advantage of tracing it directly, will be able to work more freely, and his drawing can then be reduced and still further refined in reproduction.

The preparation of a base map generally requires more time than the average geologist can spare and, when this is the case, the first step is to find a suitable base already prepared. Such a base should, besides covering the proper area, be a map of recent date if possible, and it should be of a scale large enough to show

with perfect clearness the data to be added. Well-authenticated maps and their latest editions should always be used. Naturally, an inaccurate map would seem to be a very poor base on which to present accurate data, yet some geologists have been known to use maps long out of date and full of glaring inaccuracies as a vehicle upon which to carry their detailed geology.

For preparing maps to accompany geological reports the following list of available base maps is offered as being thoroughly reliable. These maps, considered in addition to those published in miscellaneous reports, with which every geologist is more or less familiar, should meet most of the demands for base map material.

The atlas sheets and other maps published by the U. S. Geological Survey, including the large three-sheet map of the United States, scale about forty miles to one inch, and the three smaller maps of the United States; Coast and Geodetic Survey charts; maps of the several river and lake surveys by the engineer corps of the Army; U. S. Land Office state maps and township plats; U. S. post route maps, and railroad alignments. Numerous county and state maps are also available to geologists and can generally be obtained from state surveys and county officials. The general atlases recommended are Rand-McNally's, Cram's, The Times, The Century, Stieler's and many of the county atlases.

When it is necessary to compile a base map the first matter of importance to determine after having procured suitable material is the scale needed. This being a matter resting in the judgment of an author and depending upon the character of detail to be presented, it is only necessary here to point out the means by which the desired scale may be obtained. In the simpler kinds of base maps either a pantograph or the reticulation method can be used with satisfactory results. Both these methods are probably well known to most geologists. The latter consists in dividing the map to be copied, or that portion to be used in compilation, into a series of finely penciled squares of uniform size and duplicating them on the drawing paper. The map to be copied is

then sketched square by square. If the map is to be enlarged or reduced, the squares are spaced proportionally larger or smaller according to requirements. For more detailed maps photography should be used, because it is a more accurate copyist. Here, again, the matter of enlarged original is important, for the scale of the drawing should always be larger than publication size—although rarely more than twice the linear size. Another important matter relating to base maps—a matter not generally recognized—is that a drawing of a base map should not be colored or otherwise encumbered with added data. If this suggestion was always observed some geologists would find themselves possessed of clean base maps subject to reuse. This rule is now being observed in the U. S. Geological Survey with good results. It is much better to have photographic copies made, or, if the expense of a photograph is unjustifiable, to add the colors and other data on an oversheet, registering the sheet very carefully with the projection lines by a series of crosses at the intersection of all parallels and meridians and at each corner of the map.

The coloring of geologic maps is a feature of original preparation in which there is much room for improvement. The average maps submitted show contrasts either too strong or too weak and they generally show a needless lack of harmony of color. It has been found that coloring can be accomplished with better results by applying water colors in two strengths rather than to attempt to produce contrasts or distinctions by admixture. A good series of colors for this purpose are mauve, crimson lake, orange vermillion, burnt sienna, cadmium orange, chrome yellow, olive green, Hooker's green No. 2, emerald green, cerulean blue, Paynes gray, lamp black, and sepia. These thirteen colors have been selected because, when diluted, their half-tints (except chrome yellow and emerald green) will contrast with each other quite as well as the full colors, giving the painter twenty-four distinctions without admixture. It is not to be presumed that the colors named above are the only ones which should be used. There are other pigments which spread better than cerulean blue

and emerald green, but the exceptional purity of color of these two seems to warrant their use. To illustrate; take any other blue and compare its weaker tone with those of paynes gray and lamp black. It will probably be found that its tone will be slightly less distinct from the others than that of cerulean blue. Hookers green No. 2 and olive green are included in this list for the same reason and not for any particular fancy for these colors.

Aside from the colors themselves, which are relatively unimportant, the principal value of this color scheme is to make it unnecessary to mix colors in order to produce areal distinctions. Weak colors do not obscure the base map, and, when they are used to color the large areas, the strong (full) colors are left for any small areas which may stand alone, and for dikes, veins, etc. By experimentation it has been found that ample distinctions between color areas on maps can be produced without using colors in full strength, and by adopting the method suggested here the violent and unnecessary contrasts generally found in manuscript geologic maps will be obviated. Crayons are useful in the cruder kinds of work, but they rub off too easily and are not recommended. When a geologist wishes to draw a crude map to submit with his manuscript, even though it is to be printed in black, colors can safely be used to present geologic data. In fact, colors are always preferable to any attempt, on the part of the author, to use black conventions.

In compiling a base map it is of first importance to see that an accurate projection is made. No matter what character of map is to be prepared the projection should be laid out and carefully proved before the work of compiling begins. For maps of the area of the United States, and smaller areas, the polyconic projection should be used and each new map should be projected on a central meridian which will be a straight line (as the 97th meridian on a map of the United States). Tables and formulas for projecting maps are published by the U. S. Geological Survey and by the Coast and Geodetic Survey and can be obtained. Occasionally a geologist may require the use of a part of a map already published and in cases of this kind reprojection is unnec-

essary; but reference somewhere on the map should be made to the source from which the base is taken.

The question of map scales is one which should receive the attention of geologists. In the U. S. Geological Survey, which might be called the clearing house for geological reports, the scales adopted are expressed in multiples and fractions of 1 : 1,000,000, exceptions being limited to such maps as are reduced to fit its publications; and I suggest that it would be an advantage to geologists, generally, to adopt these scales for their own maps.

Structure sections form a class of illustrations in which there is also great variation in character of original preparation. These sections, like drawings of maps, should be larger than publication size. In fact, if there is complex structure of any kind, the larger scale of the drawing will facilitate its preparation. Such drawings are best prepared on profile paper in which the horizontal lines, which can be made to represent any vertical unit, are printed in blue. Much might be stated concerning methods, but let it suffice that in their preparation the greatest care should be given to details of structure. In addition to their representations of dynamic structure in which faulting, shearing, and folding should be carefully worked out, the details of the stratigraphy and lithology should be carefully indicated, although appropriate symbols need not always be shown. The effect of cross-bedding, all unconformities, lenticular masses, schistosity—in fact, all details—are important, for no one else than the author can supply missing links or correct ambiguities in such originals with safety or propriety.

Plans of mines and workings are of such a character that they cannot always be reduced to a small scale. Such drawings are best prepared on linen because they can the more readily be traced from blue prints, and when the workings on numerous levels are to be grouped into one drawing it is highly desirable that this grouping should be done by the author so as to simplify final preparation and reduce the bulk of material submitted with a report.

Of photographic originals there is little to state that is not gen-

erally known. The best prints for the purpose of illustrations are those made on velox paper of the qualities known as *Regular* and *Special*. For prints on which no retouching will be needed, paper with a glazed surface is preferable; but if any considerable amount of retouching will be required, paper with an unglazed or *mat* surface is preferable. Photographs should be combined when possible, two on a page. Those of inferior grade should not be used, even if they happen to illustrate important features, because the engravings made from them will be unsatisfactory and will mar the pages of the publication in which they are used. Pen sketches of such photographs can be prepared over blue prints and the prints bleached, leaving the drawings almost photographically correct. Another advantage is that such sketches can be engraved and the cuts used as text illustrations. Unmounted photographs are always preferable. Those which are to appear as a single plate or grouped in one plate should be placed in an envelope numbered according to the list as Plate XV., or Plate XV., *A* and *B*, and each separate print should have a corresponding number written in pencil on its back. The envelope serves as a protection to the prints and the numbers identify them.

The mechanical phase of preparation needs careful thought on the part of any author. If he simply jots down a rough sketch to be copied the sketch should be made to show exactly what is meant and leave no chance for misinterpretation. It should not be, as many are, a hazy representation of details. An important element in all illustrations of the character of those used by geologists is simplicity. They should be free from unnecessary elaboration, but be plain, unobtrusive to the eye, and directly useful.

Before disposing of the subject of original illustrations a few suggestions bearing on their preparation with respect to processes of reproduction may be appropriate. The processes now most used for the reproduction of illustrations, when classified according to their uses, and methods of printing, are of two distinct kinds—those which furnish relief plates and those in which the printing is done from a relatively flat surface and independently from the text. Illustrations printed by one of the latter processes

are called inserts because they are "bound in," where they belong; the relief plates can be printed along with the text. The difference in cost between the two kinds of processes is very great, the relief plates being furnished at very moderate cost, while the inserts are much more expensive. The processes which furnish relief plates are half-tone, zinc etching, and wax engraving. Those by which inserts are printed are lithography (engraving on stone, photolithography, chromolithography, etc.), photogravure, and photogelatin. Only photographs and wash drawings are appropriate for the half-tone process, while pen drawings, or anything in black lines and dots is suitable for zinc etching and wax engraving—the latter requiring only crude copy. Crudely prepared maps submitted to a lithographer would need to be engraved on stone and this work adds to the expense, while if a map is nicely drawn it can be reproduced by photolithography, which is one of the cheap processes. Chromolithography is the most expensive of all processes used in color printing. Photogelatin and photogravure—kindred processes—are also in the expensive class. They reproduce the same kind of subjects as the half-tone process, but have two distinct advantages over that process in that they reproduce details without showing a screen effect, and the paper used is of better quality and does not have a superficial coating. The process known as zinc etching requires a finished drawing and is the least expensive of all the photoengraving processes. It is particularly adapted to the reproduction of text figures, for which cuts should be as small as possible without affecting clearness. Half-tone cuts are not generally suitable for text illustrations because they require a coated paper of a grade not ordinarily used for printing a text.

If a map is to be in colors and the crude copy carries details which are perfectly clear it can be placed in the hands of any competent lithographer, who will be able to reproduce it in acceptable form without repreparation, but complete makeup should be furnished. If a base map is to be larger than a two-page plate and has been well prepared it can be reproduced by photolithography provided the lines are black. If of smaller size and the drawing

has been made roughly, it will be appropriate copy for wax engraving. By this process it may be said that the original is redrawn and engraved at the same time, the total cost of furnishing an engraved plate being somewhat less than the cost of a drawing, plus the cost of a zinc etching. It is only necessary to give the wax engraver correct copy; that is, all locations should be exact, and if there are doubtful points, these should be explained by penciled notes by which the size of the finished cut should also be indicated. Wax engravers are able to put into proper conventional form any crude map submitted to them to be printed in black and they will properly symbolize each special feature.

The expense incident to the reproduction of maps and other illustrations in colors by chromolithography can be greatly reduced by submitting drawings which have been prepared for direct reproduction. To do this, each feature to be reproduced in one color is prepared on a separate sheet. For this purpose tracing linen is particularly useful, as it facilitates the fitting of the colors so that they may be made to register properly when reproduced, but ample register marks should be added. In preparing maps to be reproduced in black and white the line patterns used to distinguish geologic areas are best made in fine lines and dashes arranged open or close, according to needed distinctions, and not in heavy and light lines or bars. The lines should cross the long axis of formation areas, generally at right angles.

Illustrations for reports should be forwarded in a separate package with the manuscript. The Geological Survey has found it necessary to issue regulations governing this matter because of difficulties arising from the great difference in methods pursued by various authors. The packages for a certain report should be plainly marked "manuscript" and "illustrations." Authorship should also be indicated on each package. The Geological Survey being in part a large publishing house, essentially the same method would be appropriate in dealing with other publishers. For every illustrated paper a *list* should be prepared giving a number and title for each illustration, arranged in the order in which they are referred to in the manuscript. The titles should

be concise, leaving detailed descriptions for the text. Each original should bear a title and the list number. An excellent idea is to have two carbon copies of the list made, one to be cut into strips to be pasted on each illustration, and one to accompany the illustrations. The addition of titles on the illustrations will prevent errors sometimes caused by shifting numbers during editorial work and are always useful as a means of identification.

A long experience in handling illustrations has shown that geologists, with few exceptions, approve those submitted to them for criticism without detailed examination. An instance may be cited where a geologic map fresh from the press was submitted to an eminent geologist, who returned it with this comment: "It seems to me that the Connecticut River is about five miles too far east at this point." Upon looking into the matter, it was found that the lithographer had printed the drainage wrong end up on the sheet. Such glaring errors are readily caught by a proofreader, but errors in details with which the author is more familiar than a proofreader are not so readily detected and the author should give them careful attention—not mere perfunctory examination.

JOHN L. RIDGWAY.

SOME SUGGESTIONS FOR GENERAL FIELD WORK.

Sir: In reply to your letter of October 26 requesting me to contribute any suggestions that I may have regarding methods of field work for the proposed symposium in ECONOMIC GEOLOGY:

In beginning the study of a new region I have found it of great advantage to commence by making a reconnaissance of the whole region to be covered, and if possible of the surrounding territory as well. Where the conditions are entirely unknown it is well to preface such a reconnaissance with a detailed examination of some small area to obtain a key to the stratigraphy, structure, and general type of geology to be found. After acquiring in this way some fairly definite information as a basis, a brief reconnaissance of the whole region serves to introduce one to the problems that are to be worked out and whet one's appetite for them. Such a general survey brings into view the strategic points

of attack, and, what seems to me very important, it affords a symmetrical early impression of the whole territory. One is then in a position to commence a detailed survey knowing the most advantageous places for obtaining results, and in possession of information from which an effective plan of campaign can be outlined. The usual tendency, I believe, is for one to plunge into the work at the most convenient geographic point and plough gradually through the region from one end to the other. One is inclined to feel that time is not available for taking what is apt to seem a mere sightseeing jaunt. But a reconnaissance, well made, is far more than that, and involves the closest application. In my experience the expenditure of time proves economical in the end. I have had the importance of this method brought home to me through obtaining very different ideas and results by starting at one end of a region, without a previous knowledge of the conditions elsewhere, from those obtained or obtainable by starting at the other end. It cannot be denied that there is a tendency to standardize one's ideas on the basis of early impressions, which makes it important that these impressions shall be general and well rounded, rather than based on local conditions.

Another point which impresses me as of importance is the desirability of returning to a field a second time after one has worked over the material obtained in the original examination, and before publication of the results. On this point I am sure all will agree, but it is probably true that the plan is comparatively rarely carried out. It seems to me that in cases where it is feasible such a return should be considered almost a necessity. In compiling one's results it is invariably the case that points come up which do not suggest themselves in the field and which need further corroboration. The student's thorough familiarity with the field after his original work, and after long poring over specimens, notes, maps, and manuscript, enables him to lay his finger upon the particular spots where further evidence may be available; and a short space of time spent in a revision of the crucial points will suffice to add much, in new light and con-

firmatory or adverse evidence, to the satisfactory nature of the work.

To mention a matter of minor importance, I find that it adds greatly to the convenience of the work to have whatever map is available enlarged to a scale of at least 1½ or 2 inches to the mile, so as to afford room for notes to be written directly on its face or margin. Such notes need not be inscribed immediately at the point of reference but may be connected to that point by guide-lines. In this way the map may be made a gazetteer of facts regarding the geology, these facts being naturally classified both by locality and by horizon, owing to their position on the map. I find that notes written in this way are more spontaneous and have a closer touch with the subject matter, than those inscribed in a notebook; they do not require the routine of writing, and later deciphering, a locality description. The notebook can be used for supplementary ideas and theories. When such a large scale map is used, cut in sections, and mounted, it is handy to have a small scale map as well.

ROBERT ANDERSON.

MEASUREMENT OF THE THICKNESS OF STRATA WITH THE PLANE TABLE AND TELESCOPIC ALIDADE.

Sir: This paper describes a method of measuring the thickness of strata with the plane table and telescopic alidade. In presenting this article the writer does not claim to be the inventor of the method, though when first used by him it was original to him and his associates. Since he first measured strata in this way the writer has been informed by other geologists that they have used the same method, but no one seems to have presented a written description; therefore, this paper has been prepared. The method is simply an application of surveying principles well known to all plane table operators.

The work requires two men equipped with a plane table, telescopic alidade, and stadia rod. The geologist makes the geologic observations, determines the dip and strike when they can be measured with a compass, and serves as rodman, while his asso-

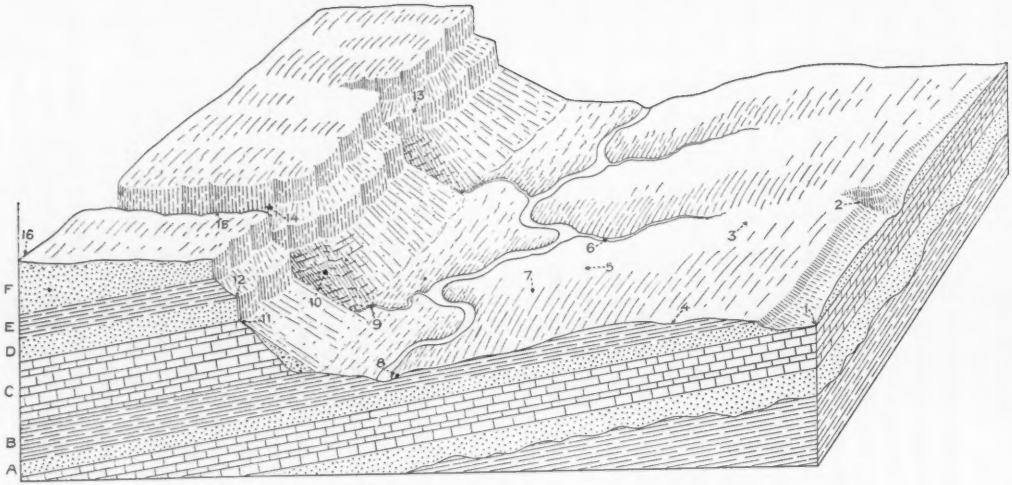

FIG. 24. Diagram of strata measured by the plane table and telescopic alidade method.

ciate operates the plane table and determines the position and relative elevation of the points occupied by the geologist. The principles are illustrated by two sections measured by the writer and an assistant. For convenience in presentation these sections are combined in one figure (Fig. 24). The plane table sheet used in the work is shown by Fig. 25. In Figure 24 the figures indicate the positions taken by the geologist and plane table operator; and in Figure 25 the figures indicate a corresponding position on the plane table sheet. Successive steps in the operation are as follows: the plane table is set up at point No. 3 and oriented with one of the edges approximately in the direction along which the section is to be measured. A compass or preferably an alidade bearing a compass is placed on the table and shifted until the needle point rests at 0; then a magnetic line is drawn to be used in future orientation if the orientation cannot be made by backsight. It is preferable, however, that sights be taken to various points which may be occupied later and lines drawn to them, in order that the plane table can be oriented later by backsights. The stadia rod is now erected at point No. 1, which is the lowest stratigraphically in the field, and its position and elevation determined by the plane table operator. Next he proceeds to point 2, where the contact of the sandstone and shale is exposed, and erects the rod (makes a station), so that the position and elevation can be determined. En route from points 1 and 2 the geologist studies the stratum and records his observations. The writer has found that the use of headings in the notebook furnishes a convenient method of showing the relation of the note to the location at which the observation was made. Thus,

Between points 1 and 2 there is a slightly ferruginous sandstone composed of angular grains of quartz intermingled with subangular grains of feldspar, etc.

At point 2 a clinometer compass reading on a fairly good exposure shows the dip to be 7°, etc.

The geologist proceeds from point to point to make his observations. He need not attempt to follow a line along the dip, but can go to points where the best data can be obtained. For the

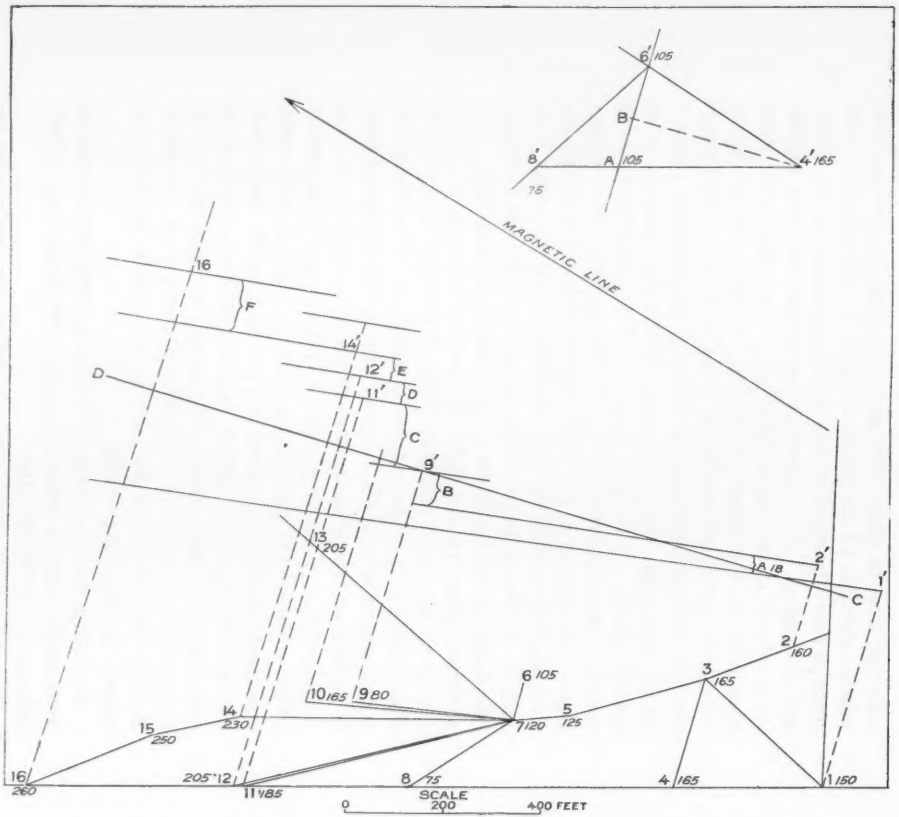

FIG. 25. Plane table sheet used in measuring strata by the plane table and telescopic alidade method.

sake of illustration it is assumed that the important datum at each point is as follows:

Point 1, at the base of stratum *a*; 2, at the top of *a*, dip and strike measurement possible; 3, plane table station; 4, fossil-bearing horizon which can also be recognized at 6 and 8; 5, turning point for the relocation of the plane table at 7; 6, see 4; 7, see 5; 8, see 4; 9, contact between *b* and *c;* 10, fossil horizon; also point from which dip and strike can be measured; 11, contact of *c* and *d*; 12, contact of *d* and *e*; 13, contact of *d* and *e*, and point to be used later in accurate determination of the direction of the strike line; 14, contact of *e* and *f*; also turning point for the relocation of the plane table at 15; 15, see 14; 16, top of *f* and highest stratigraphic point in the field.

With these points located, the elevations determined, and the observations recorded, the field work is complete; the actual computation of the thickness may be done in camp, in a hotel, or delayed until the permanent office is reached. Unless the data are desired for further field study the writer is accustomed to delay until the office equipment is available. The computation can be made mathematically if great accuracy is desired, or graphically if less refinement is necessary. For strata measured by the writer the graphical method has proven satisfactory because the limit of error in the method is less than the variability in the thickness of the beds. Geologists trained in the mathematical solution of such problems will readily see the method to be followed; hence, only the graphical solution is discussed in this paper.

In computing the thickness of the strata the first requisite is the strike line. This may have been determined in the field with a compass, but more accurate methods are desirable, especially in areas where the strata are not steeply inclined. In the illustration above, two methods of determining this line are presented: The first is based on the fact that points 12 and 13 are at the same stratigraphic horizon and were found to be at the same elevation; therefore a line on the plane table sheet passing through the points is a strike line (Fig. 25); the second is the three location method

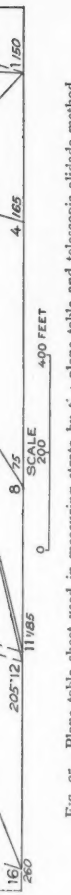

FIG. 25. Plane table sheet used in measuring strata by the plane table and telescopic alidade method.

used by geologists to determine accurately the direction of the strike and dip and the amount of the latter. This method is employed where accurate results or small angles are to be measured. The diagram at the upper right hand corner of Fig. 25, is inserted to assist in the explanation. In actual work this diagram is drawn in appropriately colored ink at its proper place on the plane table sheet, namely, from points 4, 6, and 8, but in this illustration it is transferred to an otherwise unused portion of the sheet for convenience in presentation. Points 4′, 6′, and 8′ were found to be on the same bed as determined both by lithology of the rocks and by fossils. The elevations of these three points were determined to be 165 feet, 105 feet, and 75 feet respectively; therefore, a strike line passing through No. 6 falls between Nos. 4 and 8, at a point 105 feet in elevation. This point can easily be determined either mathematically or graphically, the latter method being illustrated in the figure. The difference in elevation between 4 and 8 is 90 feet, and between 4 and 6 is 60 feet; therefore, a point between 4 and 8 at the same elevation as 6, is 60/90 of the distance from 4 to 8. By scaling the distance, point *A* (elevation 105 feet) is located. A strike line is drawn through 4 and *A*, since they are on the same bed at equal elevation. To obtain the dip, draw a line through 4′ at right angles to 6′ *A*. This line passes through *B*. Since it is at right angles to the strike it must be a dip line. The amount of dip between 4′ and *B* is the difference of elevation between the two points, in this case 165 — 105, or 60 feet. The distance between the 4 and *B* can be obtained by scaling. From the distance and difference in elevation the angle can be determined.

The direction of strike having been obtained, strike lines, shown by broken lines on Fig. 25, are drawn through the various points, 1, 2, 9, 11, 12, 14, and 16, which show the points of contact of the various beds to a convenient part of the plane table sheet and line *CD* drawn at right angles across them. This line serves as a horizontal base line from which to establish points on a profile. The position of these points is determined by scaling along the strike lines 1–1′, 2–2′, 9–9′, 11–11′, etc., from the base

line *CD*, a distance equal to the elevation of each point above the datum plane. In the illustration (Fig. 25) the datum point is 80 feet elevation, the lowest point in the field; hence, 1′ is equal to 70 feet above *CD*; 2′ is 80 feet; 11′ is 105 feet, etc. Through each profile point 1′, 2′, 9′, 11′, etc., a line is drawn at an angle to the base line equal to the angle of dip. The distance between the lines represents the thickness of the strata which can be determined by scaling. In brief, the method assumes the construction of a cross-section plane and the projection of the points on the plane in their relative position so that distances between them can be scaled.

Somewhat simple conditions have been presented above for purposes of illustration. Actual use of the method under varied conditions has shown it to be practical. The method commends itself to the writer because it permits the geologist to be free to go to exposures of the rocks and does not confine him to a strike line. It permits him to study his strata and measure the section at any angle across them. The record can be made quickly and accurately in the field and the compilation deferred to a time when facilities for computation are available. It is applicable to strata under practically all structural conditions.

The writer claims nothing new nor original for this method. It is presented for the consideration of those who are unfamiliar with, or still novices in the use of, the plane table and its accessories.

E. G. Woodruff.

REVIEWS

REVIEWS

Determinative Mineralogy, with Tables for the Determination of Minerals by Means of their Chemical and Physical Characters. By J. VOLNEY LEWIS. John Wiley and Sons, New York, 1913, 151 pp.

The book has been prepared for use in determinative mineralogy and consequently nearly one half consists of tables similar to those of Brush and Penfield's well-known "Manual of Determinative Mineralogy." A comparison of the two books shows that the tables in the present volume are a somewhat modified condensation of those in the older work. It is stated that 380 minerals are included in the tables. What minerals to include and what ones to omit is of course a difficult question to decide. If such rare minerals as lithiophilite, benitoite, pseudobrookite, trimerite and gadolinite are included, it would seem as if the commoner minerals dumortierite, fuchsite, evansite, sanidine, parisite, plumbojarosite, ilmenorutile, etc., should also have been taken up.

A brief description is given of the necessary apparatus, reagents, blowpipe operations and chemical tests, reactions for the elements, etc. Page references to Dana's "System of Mineralogy" and to his "Text-book" are given under each species. A special table is given in which the minerals are arranged first according to crystallization, and then subdivided on the basis of luster and hardness.

The small volume should prove useful as a text-book for students of elementary mineralogy, especially if it be supplemented by one on descriptive mineralogy, as suggested by the author in the preface.

W. T. SCHALLER.

Ueber Kappenquarze. By R. BECK. Centralblatt für Mineralogie, Geologie und Paläontologie, 1912, s. 693–698.

Cap quartz has long been recognized as a characteristic growth form of common quartz in tin deposits and allied ore occurrences. In the summer of 1911, Prof. Beck found specimens of cap quartz closely associated with the pegmatitic peripheral facies of the granite stock in which the tin ore at Geyer in the Erzgebirge occurs. A microscopic study of these threw considerable light on the origin of the cap quartz, and in particular on the conditions under which greisen is formed.

The individual caps, which consist of whitish quartz, vary from 1 mm. to 1 cm. in thickness, and are separated by a zone of dark colored mate-

rial which may reach a width of 1 cm. The boundary between the two is not sharp, but indistinct and gradational. The microscopic examination yielded the unexpected discovery that the caps are not single crystals but are made up of rather coarsely crystalline aggregates of quartz grains of irregular form and optical orientation. An examination of the dark zones showed that they consist of typical greisen, being made up of quartz with liquid inclusions, topaz, lithia mica and a little cassiterite. Some features of the original rock from which the greisen was derived are still preserved. Most striking are minute flakes of a colorless, presumably potash mica, which possess the same orientation as those often found parallel to the cleavages of feldspars.

This suggestion of the former presence of feldspar and hence of granite at once rules out two methods of formation of the cap quartz, namely, intermittent crystallization from aqueous solutions in open spaces and repeated crystallization from a magma. It shows that the cap quartz at Geyer was formed as a result of the replacement of granite by fluorine and silica rich gases, in other words, during the formation of the greisen. Since it has been often observed that primary quartz is incorporated into greisen without undergoing any alteration it may be assumed that some of the quartz grains which do not show the palimpsest structure represent primary granite quartz.

The individual quartz caps undoubtedly originated as crystallographic units during the pneumatolytic replacement of the granite which resulted in the formation of greisen. This uniformly oriented quartz of the caps was interrupted only by included grains of the primary granite quartz all of which possessed their own special orientation. The caps are now no longer a crystallographic unit, but, as stated above, consist of an aggregate of irregularly oriented quartz grains.

The first suggestion that this change in the quartz is due to pressure was abandoned for what seems a more probable explanation. β-quartz, the stable form above 570° C., undergoes a sudden change in its optical properties when cooled below that temperature, and is converted into α-quartz, the form stable at lower temperatures. In all probability the cap quartz was formed under conditions which gave rise to β-quartz. If this β-quartz had been free of all other substances, it is quite likely that below 570° it would have been converted into uniformly oriented caps of α-quartz. The caps included, however, the irregularly oriented granite quartz which, influencing their crystallization at the inversion point, caused them to break down into aggregates of irregularly oriented grains, though still preserving the external form of the cap crystals. The cap quartz serves, therefore, as a geological thermometer and confirms the conclusions reached from other considerations that the formation of greisen takes place at a temperature above 570° C.

JOSEPH T. SINGEWALD, JR.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

SIDNEY PAIGE AND E. RUSSELL LLOYD.

METALLIFEROUS DEPOSITS.

COPPER.

Memoire sur les Mines de Pyrite de la region de Huelva. By M. FREDERIC GOÜIN. Bulletin et Comptes Rendus Mensuels de la Societe de l'industrie minerale, 5me serie, tome II, 11me livraison de 1912, November, 1912, pp. 425–504.

The third and fourth parts of this memoir are presented comprising: Railroads and ports, mining methods, the minerals and the treatment of minerals and the mines and mining companies of the region of Huelva, Spain.

Zur Geologie der Gegend von Seibal und ihrer Kupferlagerstätten im Staate Rio Grande do Sul. Von KARL WALTHER. Zeitschrift für praktische Geologie, Oct., 1912, 404–14.

A series of early Paleozoic intrusive and eruptive rocks is overlain discordantly by Permo-Carboniferous sediments. These rocks are impregnated with copper carbonate along a series of zones which have a general north-south direction. Carbonated waters rising along a series of joints are considered to have been the bearers of the copper solutions. L.

Note on the Copper Mines of D'Arghana Vilayet de Diarbékir (Asie Mineure). By M. E. COULANT. Annales des Mines, Onzieme Serie, Tome II, 10 Livraison de 1912, pp. 281–293.

Mines exploited in year 2000 B. C. Gabbro and serpentine intruding schists; a stock-work of pyrite and chalcopyrite in gabbro believed to be of hydrothermal origin. Methods of work, treatment and production are described.

GOLD AND SILVER.

List of Nuggets found in Victoria. By E. J. DUNN. Memoirs of the Geological Survey of Victoria, No. 12, 1912.

Beginning with the heaviest nugget a list is presented comprising the following information. Whether found in quartz or alluvial; gross, net, and estimated weight; where found and depth; name of nugget; date of discovery and finders; authority and remarks.

The Chontales Mining District, Nicaragua. By ARTHUR FENST. Mining and Scientific Press, Vol. 105, No. 23, 1912, pp. 720–722, 1 map, illustrations.

The Chontales district lies on the western side of the Republic of Nicaragua about 42 miles north of east from the port of San Ubaldo, on Lake Nicaragua. Brief history of the district is presented with notes on methods of mining, treatment of ore, slimes, labor, transportation, timber, fuel, and power. Pinching and swelling quartz fissure veins cutting andesites. Carry gold and silver associated with pyrite and small quantities of argentite, galena, and sphalerite. Developed by adits. Only one shaft in district. Slinets are in most cases run to waste. Production 15,000 to 20,000 per month.

Gold Deposits of the Seward-Sunrise Region, Kenai Peninsula, Alaska. By B. L. JOHNSON. Bull. 520 *E*, U. S. Geol. Survey, 1912.

The number of producing creeks is small. Production in 1910 valued at about $2,600 for gold and $150 for silver.

The New Rand Gold-field. By A. R. SAYER. Trans. of the Institution of Mining Engrs., Vol. XLIV., part 1, 1912, pp. 4–32.

Shows the many similarities between the developed Witwatersrand field and the undeveloped New Rand 50 miles to the south. Results of drilling are presented and a detailed geologic cross section accompanies the paper. Attention is called to the probable igneous origin of the deposits and references given to papers discussing this subject.

A Study of the Ores from Austin, Nevada. By H. B. TAYLOR. School of Mines Quarterly, Columbia Univ., Vol. XXXIV., No. 1, 1912, pp. 32–39.

Describes secondarily enriched silver-bearing quartz veins in granite and connects them genetically with the granite magma.

IRON.

Die geologischen Verhältnisse der Umgebung von Melilla unter besonderer Berüchsichtigung der Eisenerzlagerstätten des Gebietes von

Beni-Bu-Ifrur im marokkonischen Rif. Von WALTER DIEKMANN. Zeitschrift für praktische Geologie, Oct., 1912, 385–403.

The author's conclusion is that the iron ores of Beni-Bu-Ifrur in Morocco are of magmatic origin. The primary ore, to which the name magnetite andesite is given, is a differentiation from an andesitic magma. The valuable ore is concentrated from this by surface weathering. L.

On the Genesis of the Pyrite Deposits of St. Lawrence County. By C. H. SMYTH, JR. Museum Bull. No. 158, New York State Museum, pp. 143–180, April, 1912.

Field relations and microscopic character of the ore deposits which occur in Grenville rocks are discussed. While there is much in favor of the hypothesis that the deposits are metamorphosed, pyritiferous, and carbonaceous shales and sandstones, the writer sums up as follows: "It appears that four periods of pyrite formation are probable: (1) A primary precipitation of pyrite contemporaneous with the formation of the sediments; (2) a concentration of this pyrite by circulating ground waters, with the addition perhaps of pyrite of deep-seated origin, before the period of metamorphism; (3) but of minor importance a recrystallization of all pyrite, accompanied perhaps by a certain amount of formation of new pyrite during metamorphism; (4) a further development and concentration of pyrite by magmatic agencies perhaps working in combination with ground waters, as outlined above, following the period of active igneous intrusion and metamorphism.

LEAD, ZINC, AND CADMIUM.

Lead in 1911, Smelter Production. By C. E. SIEBENTHAL. U. S. Geol. Survey, advance chapter from Mineral Resources of the U. S., 1911, 51 pp.

Zinc and Cadmium in 1911, Smelter Production. By C. E. SIEBENTHAL. U. S. Geol. Survey, advance chapter from Mineral Resources of the U. S., 1911, 51 pp.

Die entwickelung der oberschlesischen Zinkindustrie. Von F. KRANTZ. Kattowitz, O. S., 1911, 92 pp., 7 plates.

A history of the development of the zinc industry in Upper Silesia in its technical, economical, and sanitary aspects. L.

New Type of Wisconsin Zinc Deposit. By G. H. COX. Engineering and Mining Journal, Vol. 94, No. 22, pp. 1040–1041.

The new type of deposit is described as a "single pitch" deposit and differs in several respects from the "flats and pitches" which have long been recognized as typical of the region. The two best

examples are the Empire mine at Platteville and the Klor-Piquette mine about 4½ miles southwest of that point. L.

Sulphides of Zinc, Cadmium, and Mercury; their Crystalline Forms and Genetic Conditions. By E. T. ALLEN and J. L. CRENSHAW. Microscopic study by H. E. MERWIN. The American Journal of Science, Fourth series, Vol. XXXIV., No. 202, Oct., 1912, pp. 341–96, 1 plate.

NON-METALLIFEROUS DEPOSITS.

ASPHALT.

The Asphalt Deposits of Val de Travers. By M. F. BREYNAERT. Annales des Mines, Onzienne Serie, Tome II., 10 Livraison de 1912, pp. 317–54.

A description of asphalt impregnations in rocks of Lower Cretaceous (upper Neocomian) age.

COAL.

Production of Coal in the United States from 1814, the Date of the Earliest Record, to the Close of 1910. A table. By EDWARD W. PARKER, Division of Mineral Resources, U. S. Geological Survey.

OIL AND GAS.

A Reconnaissance Report on the Geology of the Oil and Gas Fields of Wichita and Clay Counties, Texas. By J. A. UDDEN, assisted by DRURY MCN. PHILLIPS. Bull. of the Univ. of Texas, No. 246, 1912, 292 pp.

The Douglas Oil Field, Converse County, Wyo., The Muddy Creek Oil Field, Carbon County, Wyoming. By C. E. JAMISON. Bull. No. 3, Ser. *B*, Geological Survey of Wyoming, 1912, 50 pp.

SALINES.

Kalivorkommen ausserhalb des deutchen Reiches von F. Friedensburg Kali. Zeitschrift für Gewinnung, Verarbeitung und Verwertung der Kalisalze, Vol. VI., Nos. 22 and 23, 1912.

Die Physikalisch-chemischen Bedingungen bei der Bildung der Salzlagerstätten und ihre Anwendung auf geologische Probleme. Von SVANTE ARRHENIUS und RICHARD LACHMANN. Geologische Rundschau, Band III., Heft 3, May, 1912.

WATER RESOURCES.

Domestic Water Supplies for the Farm. By MYRON L. FULLER, S.B. John Wiley & Sons, 1912. 172 pp.

The object of the book is to explain to the agriculturist something of both the advantages and dangers of the common sources of domestic water supplies, including surface water, springs, and underground waters and to point out to him the danger signals and indicate the steps to be taken to safeguard his supplies.

Surface Water Supply of the United States, 1910. Part I., North Atlantic States. By C. C. BABB, C. C. COVERT, and R. H. BOLSTER, under the direction of M. O. LEIGHTON Water-supply Paper No. 281, Geological Survey, 1912.

Surface Water Supply of the United States. Part X., The Great Basin. By E. C. LARUE, F. F. HENSHAW, and E. A. PORTER. Water-supply Paper, U. S. Geol. Survey, No. 290, 1912, 264 pp.

Water Resources of California. Part II. By H. D. MCGLASHAN and H. J. DEAN. Prepared under the direction of JOHN C. HOYT. Water-supply Paper No. 299, U. S. Geological Survey, 1912.

Das Auftreten gespannten Wassers von höherer Temperature in den Schichten der oberen Kreide formation Nord böhmens. Von J. E. HIBSCH. Jahrbuch der Kaiserlich-Königlichen Geologischen Reichsanstalt, LXII., 2 Heft, 311–331, Wien, 1912.

The results of the study of a number of artesian wells in northern Bohemia, in some of which the water is above the normal temperature.

A Preliminary Report on the Quincy Valley Irrigation Project. By HENRY LANDES and others. Bull. Washington Geol. Survey, No. 14, Olympia, 1912, 49 pp.

GENERAL, REGIONAL, AND THEORETICAL.

Description des Mineraux du Congo Belge (Deuxième Memoire). By H. BUTTGENBACH. Extract from the Annales de la Société Geologique de Belgique, 1912, 45 pp.

A description of the minerals of the Belgian Congo in the order adopted by Dana. Indexed by localities and by mineral species.

Notes on the Zomelahuacan Mining District, State of Vera Cruz. By A. G. WHITE. Informes y memorias del Institute Mexicano de Minas y Metalurgia, Tome III., No. 1, pp. 49–52, 1912–13.

History obscure; auriferous deposits probably worked since Span-

ish conquest. Besides gold ores, copper, iron, and lead ores are widely distributed. The ore deposits are found at or near the limestone contact associated with metamorphic rocks along lines of contact and fracture planes . . . and owe their origin to the segregation of the metals in the igneous rocks and to precipitation from hydrothermic solutions, circulating through the fractures and crushed zones; subsequent denudation of the rocks and subaerial agencies contributing to their secondary enrichment. A promising future is predicted.

The Metallogeny of the Japanese Islands. By C. IWASAKI. Journal of the College of Science, Tokio Imperial University, Vol. XXXII., Article 8, Nov. 3, 1912, 23 pp., 1 map.

States that during the consolidation of a magma, emanations are exuded, by the petrifaction (solidification) of which ore deposits are formed. Believes a definite process of deposition of emanations determines the order of solidification. Divides the ore bodies of igneous origin into 5 classes: magmatic segregations, contacts, replacements, mineral veins and impregnations. Divides the Japanese Empire into 5 metallogenetic provinces and associates with each certain "ore bringers" (igneous rocks) and certain types of ore body. Gives table showing distribution of minerals by provinces and the order of their solidification in each province.

The Mining and Quarry Industry of New York State. Report of Operations and Production during 1911. By D. H. NEWLAND. Museum Bull., New York State Museum, No. 161, Albany, 1912, 114 pp.

The total mineral production of the State of New York in 1911 was valued at $31,573,111, a decrease of 10 per cent. from that of 1910. Of the various products clay is the most important followed by building stone, iron, cement material, etc. L.

Annual Report of the Minister of Mines for the year ending 31st December, 1911. Victoria, B. C., 1912, 295 pp.

An account of mining operations for gold, coal, etc., in the province of British Columbia.

Bilder über metasomatische Prozesse auf alpinen Erzlagerstätten. Montangeologische Mitteilungen aus dem Institute für Mineralogie u.s.w. an der montanistischen Hochschule in Leoben Nr. VI. Von B. GRANIGG. Österreichische Zeitschrift für Berg- und Hüttenwesen (Nov. 30, 1912), 675–6.

The author proposes to present a series of colored plates illustrating graphically the results of metasomatic replacement. The first plate only with its explanation is presented in this number. L.

Introduction to the Study of Minerals, a Combined Textbook and Pocket Manual. By AUSTIN FLINT ROGERS. McGraw-Hill Book Co., 512 pp.

From the preface: "The work is intended primarily as a textbook for a one-year course in mineralogy. While full enough for class work it is condensed enough for field work. . . . Two hundred minerals have been included in the descriptions. . . . The distinctive features of this book are (1) the description of the optical and microscopic properties of crushed fragments, cleavage flakes, and recrystallized products; (2) six new determinative tables. These are useful in getting the student familiar with the terms used as well as in the actual determination of minerals; (3) a numbered list of the occurrences of each mineral, establishing what the author calls paragenetic varieties; (4) a glossary of terms. Synonyms and varieties are usually given in the glossary rather than in the text. In a subject like mineralogy a glossary seems almost a necessity."

GENERAL STATISTICS.

City Products of the United States, 1910, with Corresponding Totals for 1909. A table. By EDWARD W. PARKER, Statistician in Charge; JEFFERSON MIDDLETON, Statistician. Mineral Resources, U. S. Geological Survey.

Statistik des Bergbaues in Österreich für das Jahr, 1911, Erste Lieferung: Die Bergwerks-production. 236 pp. Wien, 1912.

The total value of the mineral production in the Austrian Empire in 1911 was 413,759,709 kronen, an increase of over 12,000,000 kronen. Bohemia was the largest producer with 44.39 per cent. of the total. Over 86 per cent. of the total value was in coal. L.

Gold, Silver, Copper, Lead, and Zinc in the Western States and Alaska in 1911. Mine Production. By A. H. BROOKS, C. N. GERVIN, V. C. HEIKES, C. W. HENDERSON, H. D. MCCASKEY, and C. G. YALE. U. S. Geol. Survey, Advance chapter from Mineral Resources of the U. S., Calendar year 1911, 791 pp.

Mineral Production of Virginia; Biennial Report, for the Years 1909 and 1910. By THOMAS LEONARD WATSON. Virginia Geological Survey, Bull. No. VI., 120 pp.

Mineral Products of the U. S., Review of Conditions and Output in 1910 and 1911. By EDWARD W. PARKER. Advance chapter from Mineral Resources of the United States, year 1911, U. S. Geol. Survey.

Mineral Products of the United States 1902 to 1911. A table. By EDWARD W. PARKER. U. S. Geol. Survey.

UNCLASSIFIED.

A Study of Sand Lime Brick. By S. W. PARR and T. R. ERNEST. Illinois State Geol. Survey, Bull. No. 18, 1912, 77 pp.

Diatomaceous Earth and its Occurrence in Victoria. By D. J. MAHONY. Bull. No. 26 of the Geol. Survey of Victoria, 1912, 16 pp. and map.

Describes the nature and uses of diatomaceous earth and presents detailed account of a number of deposits. The Victoria deposits have been mined to a limited extent. The better grade of material is always associated with basalt (in beds) belonging to the newer volcanic series which is probably all Pliocene or younger in age.

Portland Cement, its Composition, Raw Materials, Manufacture, Testing, and Analysis. By RICHARD K. MEADE. The Chemical Publishing Co., Easton, Pa., 1911, 501 pp.

Deposits of Borate of Lime (Asia Minor). By M. COULBEAUX. Annales des Mines, Onzienne Series, Tome II., 10e Livraison de 1912, pp. 294–315.

General notes on uses, consumption, production, and sale are given; then history and description of the deposits. The mineral is called pandermite and occurs as layers and as stocks in beds of gypsum; is assigned a fumarolic origin.

Phosphates in Idaho and Montana. By A. R. SCHULTZ, R. W. RICHARDS, and J. T. PARDEE. Bull. 530–*h*, U. S. Geol. Survey, 1912, 27 pp.

SCIENTIFIC NOTES AND NEWS[1]

THE INTERNATIONAL GEOLOGICAL CONGRESS will hold its Twelfth Session at Toronto from August 7 to 14 inclusive. Admission as a member of the congress may be secured on payment of a fee of five dollars. Members are entitled to take part in the meetings and discussions, and to receive, after the meeting, a copy of the *Transactions*. Remittances should be made by post office money order to the Secretary, Twelfth International Congress, Victoria Memorial Museum, Ottawa, Canada.

The topics selected for discussion at the meetings are as follows:

1. Coal Resources of the World.
2. Differentiation in Igneous Magmas.
3. The Influence of Depth on the Character of Metalliferous Deposits.
4. The Origin and Extent of the Pre-Cambrian Sedimentaries.
5. The Subdivisions, Correlation, and Terminology of the Pre-Cambrian.
6. To what Extent was the Ice Age Broken by Inter-Glacial Periods?
7. The Physical and Faunal Characteristics of the Palaeozoic Seas, with Reference to the Value of Recurrence of Seas in Establishing Geological Systems.
8. Miscellaneous.

All contributions to the discussion must be in the hands of the General Secretary by May 1, 1913, if they are to be printed in time for distribution before the meeting. They may be submitted in French, English or German.

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

Many interesting excursions are planned for the periods preceding and following the meeting. While membership in the congress is not restricted, these excursions will be confined to such members of the congress as are geologists, mining engineers, geographers and others engaged in the study or application of some branch of geology. Detailed information concerning the excursions may be obtained from the secretary.

AT A CONFERENCE held in the rooms of the Massachusetts Institute of Technology on January 13, 1913, the question of "The Pre-Cambrian Nomenclature" formed the subject of discussion. A number of geologists residing in Boston and vicinity were present. The general conclusion of the conference as to the term *Algonkian* is expressed in the following resolution:

In the Judgment of the Undersigned it is not as yet possible to divide the Pre-Cambrian by any universally applicable line of correlation and stratigraphic division. We deprecate the use of the term *Algonkian* since it does not definitely connote anything further than *Pre-Cambrian.* This statement involves no opinion regarding literary questions raised by shifting of definitions or regarding the original usage of Archean and other terms which have been applied to the Pre-Cambrian.

(*Signed*) J. B. WOODWORTH,
C. H. WARREN,
H. W. SHIMER,
W. LINDGREN,
ERNEST HOWE,
R. A. DALY,
L. C. GRATON,
ALFRED C. LANE.

F. L. RANSOME left Washington early in March for a brief visit in New Mexico and Texas.

E. S. BASTIN, of the U. S. Geological Survey, is delivering a course of lectures in economic geology at the University of Chicago.

H. G. FERGUSON, of the U. S. Geological Survey, recently examined the reported discoveries of gold in Carboniferous shales of Pushmataha County, Oklahoma.

R. H. WOOD, of the U. S. Geological Survey, who has been engaged in the examination of the Hominy Quadrangle, Oklahoma, during the fall and winter, has returned to Washington.

THE following papers have been read at recent meetings of the Geological Society of Washington: Chase Palmer and E. S. Bastin, "Certain Metallic Minerals as Precipitants of Silver and Gold"; J. M. Hill, "The Zinc-lead Deposits of the Yellow Pine District, Nevada"; R. W. Richards, "Nitrate Deposits near Melrose, Montana."

AN item of the public buildings act passed by the last Congress, and signed by the President, authorized the appropriation of $2,596,000 for a modern office building to accommodate the United States Geological Survey and several other related bureaus. The act authorizes the immediate appropriation of $596,000 so that after the preparation of plans the construction may proceed at once.

DR. A. F. ROGERS, associate professor of mineralogy and petrography at Stanford University, has been elected a member of the Mineralogical Society of Great Britain. Professor Rogers is the author of "Introduction to the Study of Minerals," recently published by the McGraw-Hill Book Company.